UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 536

Contribution from Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER January 26, 1918

THE MEDITERRANEAN FRUIT FLY IN HAWAII

By

E. A. BACK, Entomologist, and C. E. PEMBERTON,
Assistant Entomologist, Mediterranean and
other Fruit-Fly Investigations

CONTENTS

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CONTENTS.[1]

INTRODUCTION.

The Mediterranean fruit fly (*Ceratitis capitata* Wied.) (fig. 1; Pl. 1, fig. 1) since its discovery in the Hawaiian Islands in 1910 has caused a serious and permanent check upon horticultural pursuits in these islands. The history of this pest shows that it has been gradually spreading to all tropical and subtropical countries. The frequency with which infested fruits from Hawaii are being discovered and condemned at California ports by representatives of the Federal Horticultural Board indicates that this fruit fly might have become established in parts of California and in our more Southern States and might now be doing untold injury to fruit interests but for the efficient quarantine maintained on the Pacific coast by State and Federal authorities. It is feared, however, that the Mediterranean fruit fly ultimately will be able to find some unavoidable weakness in the quarantine work and eventually become established on the mainland of North America.

The investigations reported in this publication have been carried on by the Bureau of Entomology, United States Department of Agri-

[1] It has been found necessary to omit a bibliography consisting of about 350 references accompanied by brief résumé material. Reference should be made to Silvestri, Bulletin No. 3, Hawaiian Bd. Agr. and Forestry, for the most complete printed bibliography.

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culture, under the immediate supervision of Mr. Charles L. Marlatt, assistant chief of the bureau and chief of the Division of Tropical and Subtropical Fruit-Insect Investigations. This work was undertaken during September, 1912, primarily to make available for mainland fruit-growing interests information that will prove of inestimable value in determining the extent of the possible distribution of this pest and the factors of control which will be most important in eradicating newly discovered outbreaks.

The senior writer wishes to acknowledge his obligations to Mr. Marlatt, who has greatly aided these investigations by his direction, and to express his appreciation of the assistance rendered by his associates, Messrs. C. E. Pemberton and H. F. Willard.

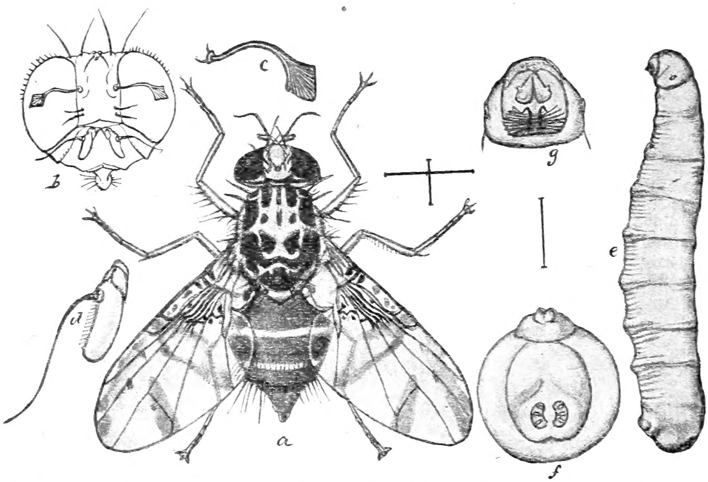

FIG. 1.—The Mediterranean fruit fly (*Ceratitis capitata*): *a*, Adult female; *b*, head of same from front; *c*, spatula-like hair from face of male; *d*, antenna; *e*, larva; *f*, anal segment of same; *g*, head of same. *a* and *e*, Enlarged; *b*, *g*, *f*, greatly enlarged; *c*, *d*, still more greatly enlarged. (Howard.)

COMMON NAMES.

The common name "Mediterranean fruit fly" was first used by Frogatt in 1899 to distinguish *Ceratitis capitata* from other fruit flies found in Australia. At the present time this name is the most widely used and most satisfactory of the common names by which this pest has been known and will be used by the writers. Other common names found in literature are "the fruit fly," "the maggot," "peach fly," "peach maggot," "fruit grub," "apricot worm," "trypeta fly," "West Australian fruit fly," "orange fly," and "orange fly trypeta."

ORIGIN.

Although Wiedemann first described *Ceratitis capitata* from specimens collected by Daldorf, supposedly in the East Indies, the failure of subsequent entomological exploration in the Indo-Malayan region to

locate this species, except where it is known beyond question to have been introduced; has led entomologists to seek its original home elsewhere. Known facts concerning the artificial spread of this pest narrow its probable origin to the African continental area. According to Bezzi, the genus Ceratitis is of African origin. Information gained by various writers indicates that southern Europe is not its native home, although it has been recorded from this region for many years. Leonardi states that the Mediterranean fruit fly was not recorded as a pest in southern Italy until 1863, nor in Sicily until 1878. Had it been a native of Italy its ravages, as were those of the olive fruit fly (*Dacus oleae* Rossi), would have attracted the attention of writers prior to this time. While De Brême first records specimens reared in southern Spain in 1842, it is easier, in the light of more recent investigation, to believe Spain to be an adopted rather than the original home. Compere states that in 1903 there was living at Carcagente, Valencia County, Spain, an aged priest who could well remember the time in his childhood that peaches in that part of Spain were free from fruit-fly attack. Compere is also authority for the statement that commission merchants at Seville found that the pest was spreading farther inland to the north every season, even as late as 1903. The work of Graham (1910) and Silvestri (1912) has proved that *C. capitata* is present in the little-developed West African countries of Nigeria, Dahomey, and the Kongo, and Gowdy found the species already established in Uganda as early in the development of that country as 1909. These records, coupled with the information by the South African entomologists regarding its spread into the southern part of the African Continent, lend color to the statement of Silvestri that the natural habitat of *Ceratitis capitata* is "certainly tropical Africa south of 8° N. latitude." Silvestri, however, is of the opinion that one can not state whether the whole of this region should be considered as the natural habitat, or only the western portion, until careful studies have been made in French Equatorial Africa and British East Africa. Further exploration of the west coast of Africa north of 8° north latitude is very likely to establish new records of distribution and extend somewhat these limits of origin to include more semitropical territory.

DISTRIBUTION.

The Mediterranean fruit fly is at present established on every continent except that of North America. It has been recorded from the following regions:

Europe: Spain, France, southern Italy, Sicily, Greece, and Malta.
Asia: Asiatic Turkey (Beirut, Jerusalem, Jaffa.)
Africa: Egypt (Cairo and Kafir el Zayet), Tunis, Algeria, the Azores, Madeira Islands, Canary Islands, Cape Verde Islands, Dahomey, southern Nigeria, the Kongo, Cape Colony, Natal, Delagoa Bay, southern Rhodesia, British East Africa, Uganda Protectorate, Mauritius, and Madagascar.

Australasia: Western Australia, New South Wales, Victoria, and Queensland, northern New Zealand, and Tasmania.

South America: Brazil and Argentina (Buenos Aires).

North America: Bermuda Islands.

Hawaiian Islands.

MEDITERRANEAN REGIONS.

The dates of the first discovery of the Mediterranean fruit fly in the countries bordering on the Mediterranean can not be used with precision in establishing a chronology of dispersion, since the pest may have been present many years prior to the first entomological observations recorded unless statements to the contrary are made in literature. Aside from our first record of establishment in Mauritius by Latreille in 1817, the earlier records refer to damage in the Mediterranean region. According to MacLeay this pest was well established in the Azores, Cape Verde, and Madeira Islands as early as 1829, and was the source of much injury to oranges arriving at London from these islands. It was first recorded from Spain in 1842, from Algeria in 1859, and from Tunis in 1885. Compere gives us our first records of its presence in Egypt at Port Said and in Asiatic Turkey at Beirut, Jaffa, and Jerusalem in 1904. During the same year, Cartwright records the infestation of oranges at Kafir el Zayet (Egypt) and four years later Froggatt found many infested oranges in the Cairo (Egypt) markets. Literature does not record the presence of this pest in Malta until 1890, although it was known to have become established there about 1875. In France the Mediterranean fruit fly was reared from apricots at Courbevoie, in the environs of Paris, in 1900, and by 1904 the fruit industry around Maritimes was ruined, according to Hooper. In 1916 the citrus crops in Attica (Greece) and Epirus (Southern Albania) were reported infested.

AFRICA.

Very little is known regarding the general distribution of the Mediterranean fruit fly throughout the great central portion of the African continent. While it is known to be a serious pest along the Mediterranean shores and to have spread into the southern portion, too few entomological observations have been made to warrant statements concerning spread throughout the more tropical regions. Graham in 1910 and Silvestri in 1913 state that it occurs in Dahomey, southern Nigeria, and the Kongo. Gowdey's records from Uganda in 1909 are the first from tropical East Africa, although Anderson states in 1914 that he had found *C. capitata* infesting coffee cherries in British East Africa. In 1912 Jack lists *C. capitata* as abundant throughout southern Rhodesia, but Morstatt states definitely that the pest did not occur in coffee cherries in German East Africa during 1913 and 1914.

The first record of injury caused by the Mediterranean fruit fly in South Africa was made by Miss Ormerod in 1889; but, as Mally states

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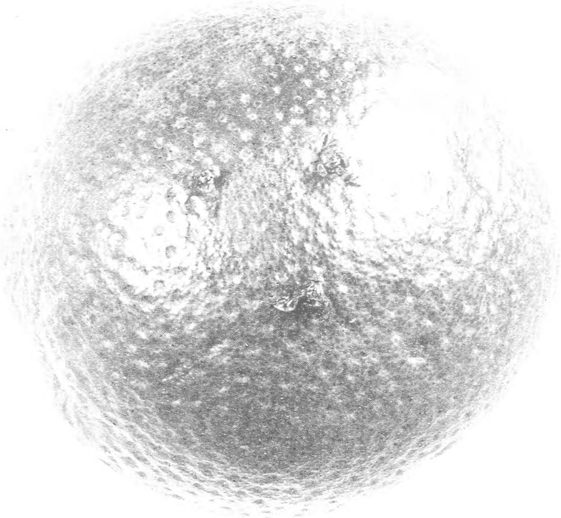

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THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—Three adults of the Mediterranean fruit fly (*Ceratitis capitata*) about natural size, attempting to oviposit in an orange; note the relative size of flies and fruit. FIG. 2.—Ripe apple showing many punctures in the skin made by *C. capitata* in confinement. (Original.)

in 1904, it was introduced many years before. In 1893 Bairstow writes that he was familiar with *C. capitata* in South Africa in 1880, and that the Rt. Rev. Bishop Richards remembered damage done as far in the past as 40 years. In 1903–4 Fuller records *C. capitata* as one of the newly observed pests among the Natal orchards. It is not known whether the introduction in South Africa was by infested fruit from the Madeiras or by the gradual spread overland along the coastal regions, although the Madeiras seem the more probable source.

C. capitata was first recorded from Madagascar during 1914, when it was found seriously injuring the peach crop.

AUSTRALASIA.

Western Australia.—The Mediterranean fruit fly was first recorded in literature as a pest in Australia in 1897 by Fuller, who states that it had been known to have been established in western Australia for about two years in Claremont and Perth and along the Swan River, especially at Guildford. According to Despeissis, the first report of injury in Australia was made to the Bureau of Western Australia in 1894, which was, in his opinion, about one or two years after the date of its actual introduction. The pest has since been recorded from as far north as Geraldton and Northampton and as far south as Bunbury.

New South Wales.—In New South Wales the Mediterranean fruit fly was first reared in 1898. French found that peaches imported into Victoria from Sydney were infested and notified Froggatt. Within a few days Froggatt was able to verify this record by rearings of his own from fruit supposed to have been infested by the Queensland fruit fly (*Bactrocera tryoni* Froggatt). As Froggatt had been on the watch for *C. capitata*, it is probable that it became established about Sydney during 1898, although Rose, in 1897, states that in the northern part of New South Wales, at Warialda, peaches and nectarines had been nearly all destroyed in 1897 by a fruit fly first appearing about 1895 and identified by Froggatt as probably *C. capitata*. According to Froggatt, the pest has spread throughout all the citrus orchards of New South Wales to a greater or less extent.

Victoria.—Editorial comment in 1907 states that serious infestation of *C. capitata* had been recently discovered in the orchards in Goulburn Valley and farther west at Bendigo and at Horsham, and Froggatt is authority for its establishment at Albury and for the statement that it is present throughout the northern half of Victoria.

Queensland.—There are very few references to the presence of *C. capitata* in Queensland. Froggatt states, in 1909, that for a long time it was believed that it was not to be found in this part of Australia, but that, while it might not be abundant, he had specimens

from Brisbane. Voller, in 1903, mentions Brisbane, Toowoomba, and Warwick as places especially subject to *C. capitata* attack.

Tasmania.—The Mediterranean fruit fly became established in Tasmania about Launceston during the early part of 1899 and, according to Lea, attacked apples, pears, and peaches. As the result of a meeting of the Tasmania Council of Agriculture, held on June 1, to discuss correspondence regarding establishment and methods of eradication, a vigorous clean-culture campaign was authorized, which apparently was responsible for the eradication of the pest. No cases of infestation have since been observed in Tasmania fruit.

New Zealand.—Kirk states in 1901 that the Mediterranean fruit fly had not, up to that time, appeared in any New Zealand fruit-growing district. Two outbreaks were later recorded, at Blenheim and at Napier, respectively, but were reported to have been quickly stamped out by the destruction of the fruit and treatment of the soil. A third instance of temporary establishment in New Zealand was recorded in 1908 at Davenport. At present the Mediterranean fruit fly is not known to exist in New Zealand.

Islands about Australia.—In 1904 Kirk states that he had never reared *C. capitata* from fruits received in New Zealand from the islands of Suva, Nukualofa, Vavau, Rarotonga, Mangaia, Heratine, and Samoa.

BERMUDA ISLANDS.

The Mediterranean fruit fly was not recorded from the Bermuda Islands until 1890, when specimens of infested peaches were sent Dr. C. V. Riley. It was known as a pest in Bermuda during the 25 years previous, and is supposed to have become established about 1865, when a vessel carrying a cargo of fruit from the Mediterranean region, bound for New York, was forced by severe storms to discharge her cargo in Bermuda.

WEST INDIES.

There are no known records of the presence of *Ceratitis capitata* in the West Indies. The fact that the Jamaica Botanical Department in 1900 published a bulletin on orange culture and diseases, by Borg, in which reference is made to *C. capitata* as a pest of the orange, has led some to believe that the Mediterranean fruit fly has become established in Jamaica. The subject-matter of this bulletin was originally presented before the Malta Archeological and Scientific Society and contains nothing to warrant the conclusion that the author was dealing with the subject except in a most general way, particularly as he speaks of the fly occurring only about the Mediterranean.

Ballou, in an article published in 1913 on the prevalence of some pests and diseases in the West Indies during 1912, states that "fruit-fly" attacks were not so general in Dominica as in former years. The editor of the Review of Applied Entomology erroneously iden-

tified the "fruit fly" as "*C. capitata.*" Ballou has since denied in correspondence that *C. capitata* was the insect in question.

SOUTH AMERICA.

Dr. L. O. Howard first identified the Mediterranean fruit fly from South America from specimens reared from peaches sent him by Dr. H. von Ihering in 1901. Compere, in 1904, and Lounsbury, in 1905, found the pest in the States of Sao Paulo and Rio de Janeiro. In 1906 Hempel states that *C. capitata* was the most common of the fruit flies attacking peaches in Sao Paulo.

In writing of fruit culture in Argentina in 1905, Lounsbury states that peaches near Buenos Aires were badly affected by an undetermined species of fruit fly which he thought likely to be *Ceratitis capitata.* Silvestri definitely records *C. capitata* from Buenos Aires, presumably as a result of this statement of Lounsbury.

HAWAIIAN ISLANDS.

The Mediterranean fruit fly was first observed in the Hawaiian Islands by Mr. D. T. Fullaway, who captured a living adult in the insectary at the U. S. Department of Agriculture Experiment Station on June 21, 1910. During the following September another adult was captured by Terry and Perkins on the laboratory windows of the Hawaiian Sugar Planters' Association. Observations made in the field during September by Terry showed that the pest was already established in the Punchbowl district of Honolulu on oranges and limes, and from that time new records of infestation were rapidly brought to light. By October, 1911, the pest had already become established on the island of Kauai, and was known to exist on Molokai at least by January, 1912, when it was first recorded from the Kohala district of the island of Hawaii. During March, 1912, specimens of infested coffee cherries were reported from the Kona district of Hawaii. The first records of establishment in the Puna district of Hawaii were made during March, 1913, when infested oranges and peaches were found at Naalehu and Hilea. Peaches were not reported infested in the Hilo district of Hawaii until the spring of 1914, but soon after infestations were found throughout the Hilo and Hamakua districts. The fruit fly was found established on the Island of Maui by May, 1912. By July, 1914, the Mediterranean fruit fly had spread to every important island of the Hawaiian group, and at present is well established in every village and wild guava scrub examined by the writers. Judging from the rapidity with which this pest has spread throughout new districts in Hawaii, the writers agree with Ehrhorn that the pest secured its first foothold in Hawaii at Honolulu about 1907, although there are several well-informed horticulturists in Honolulu who believe establishment occurred even one or two years earlier.

SOURCE OF HAWAIIAN INFESTATION.

There is little doubt that the Mediterranean fruit fly was carried to the Hawaiian Islands from Australia on one or more of the ships

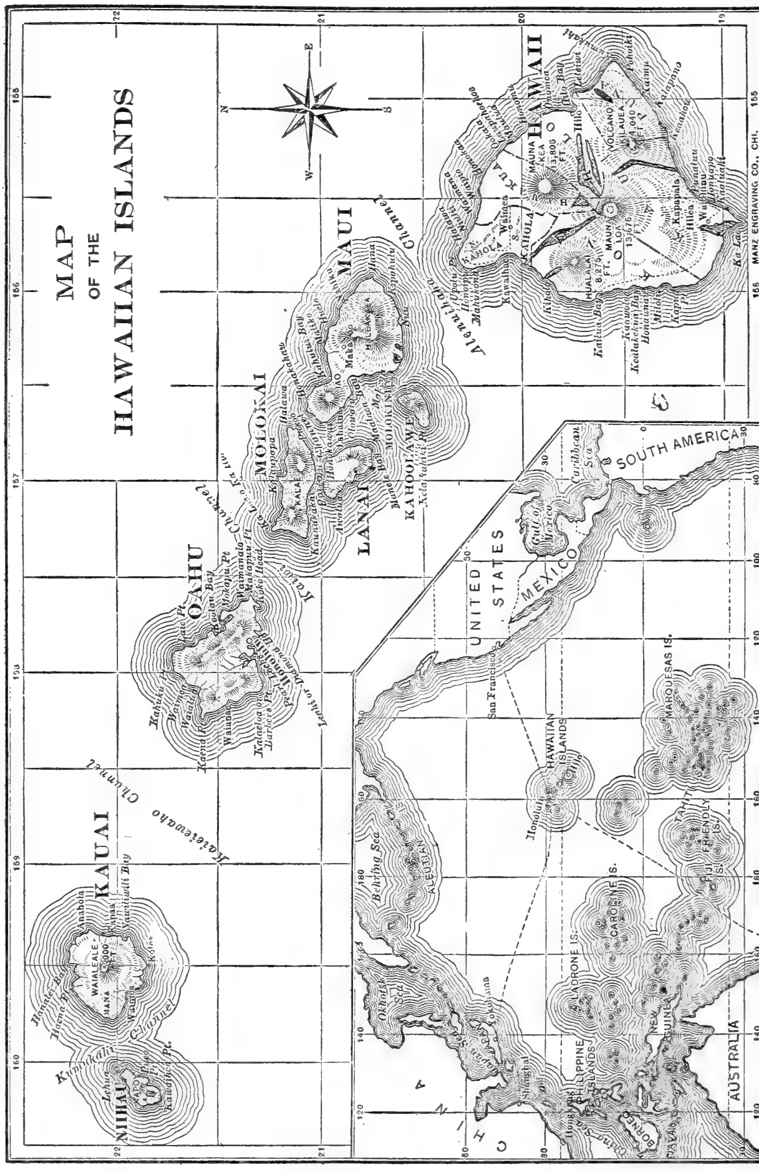


FIG. 2.—Map of the Hawaiian Islands, showing their relative position and their relation to one another in the distribution of the Mediterranean fruit fly.

plying between the ports of these two countries. Before this fruit fly was known to have become established about Honolulu, Compere, as a traveler between Australia and Honolulu, observed *C. capitata* larvæ emerging from host fruits stored on the deck of his vessel and

pupating in the corners of the fruit containers and in secluded spots about the deck. It would have been quite possible for larvæ thus emerging to have completed their development during the days required for the voyage between Sydney and Honolulu and emerged as adults while the ship lay at anchor at Honolulu within several hundred yards of host fruit trees. As the Mediterranean fruit fly did not become established about Sydney and the eastern portion of Australia until 1898–1907, its establishment about Honolulu between 1907 and 1908 came as a natural sequence. This is most forcibly brought to the attention of those interested in horticultural development when they appreciate the frequency with which this pest has attempted to bridge the Pacific between Honolulu and San Francisco since its establishment at Honolulu, as indicated by the interception of infested fruit at San Francisco by officers of the Federal Horticultural Board.

CONDITIONS FAVORABLE TO ESTABLISHMENT IN THE HAWAIIAN ISLANDS.

CLIMATIC CONDITIONS IN HONOLULU.

The climate of the littoral regions of Hawaii, and up to an elevation of 1,500 feet, is most favorable to the establishment and rapid increase of *C. capitata*. At Honolulu the temperature very rarely drops as low as 58° F., and then only for a few hours during one or two nights in the year. The data in Table I, taken from the monthly meteorological summaries of the U. S. Weather Bureau at Honolulu for 1914, are given as a fairly reliable guide to the ranges in temperature throughout littoral Hawaii.

TABLE I.—*Temperature and relative humidity at Honolulu during 1914.*

Month.	Temperature.									Relative humidity.		
	Maximum.	Minimum.	Daily range.			Mean at [1]			Mean of maximum and minimum.	Maximum.	Minimum.	Mean.
			Maximum.	Minimum.	Average.	6 a. m.	2 p. m.	9 p. m.				
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	P. ct.	P. ct.	P. ct.
January	78	60	18	6	10	67.4	74.0	68.9	[2]69.1	83	50	66.4
February	81	61	14	8	11.4	66.2	72.4	68.3	71.4	82	52	70.9
March	80	57	15	7	10.5	67.5	74.8	89.6	70.9	86	53	68.6
April	82	60	15	7	10.7	68.6	75.8	70.9	72.5	81	52	68.7
May	83	66	14	6	9.4	72.6	79.9	74.6	74.3	82	56	70.1
June	83	69	12	6	9.1	74.0	80.4	76.0	76.6	80	58	68.8
July	85	70	15	6	9.2	75.2	81.5	76.3	78.4	81	62	69.6
August	86	71	12	5	9.1	76.0	81.4	76.8	79.0	80	58	69.2
September	87	70	12	6	8.1	75.9	80.6	77.0	78.7	85	62	71.4
October	83	67	14	7	9.4	73.6	79.7	75.1	77.0	74	60	68.0
November	83	65	13	5	10.2	71.4	77.2	72.9	74.6	85	52	70.5
December	80	61	14	7	10.7	67.6	74.3	69.7	71.1	89	60	72.7

[1] Compiled from 1914 and 1915 data, taken from the 1916 Hawaiian Annual.
[2] The normal mean for January is 71.1° F.

It will be observed that the daily range is very small, averaging between 8 and 11 degrees, and that the normal monthly mean temperatures range between 70.9° and 79° F. In Table II are given the monthly and yearly means, together with the yearly maximum and minimum temperatures, recorded at different places on the islands of Hawaii, Maui, and Oahu, which, at their respective elevations, represent the variations in range of temperature from that in Honolulu, to be found at points in Hawaii where host fruits are grown.

TABLE II.—*Monthly and annual mean and maximum and minimum temperatures of representative localities in Hawaii where host fruits of the Mediterranean fruit fly may be grown.*

Locality.	Elevation.	Monthly mean temperatures.												Annual.		
		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.	Highest temperature recorded.	Lowest temperature recorded.
Island of Oahu:	*Feet.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
Honolulu	111	70.0	69.7	71.4	73.3	74.3	75.3	76.4	78.1	76.8	75.2	74.7	72.4	74.0	85	58
Waialua Mill	30	70.4	68.7	71.0	72.7	73.4	74.4	75.8	77.0	75.9	73.9	72.8	70.5	73.0	91	55
Waianae	6	71.3	70.4	71.9	73.8	74.8	77.3	79.2	80.0	79.3	75.5	74.8	73.2	75.1	91	52
Schofield Barracks	990	66.6	65.8	67.4	68.9	69.8	71.0	73.0	74.0	73.2	71.2	66.4	68.1	69.6	89	51
Tantalus Heights	1,300	63.6	64.1	66.3	67.2	68.0	67.7	69.3	70.4	69.1	68.5	67.4	65.6	67.3	84	54
Island of Maui:																
Kaanapali	12	70.2	70.4	71.4	74.0	76.0	77.3	79.3	80.0	79.4	76.5	75.2	73.0	75.2	92	57
Wailuku	250	68.8	69.2	69.8	72.2	73.0	74.1	75.5	77.4	75.8	74.0	72.8	70.9	72.8	89	56
Haiku	700	67.2	67.2	68.6	69.6	70.7	70.7	72.8	74.2	72.4	71.8	70.4	68.7	70.4	83	57
Island of Hawaii:																
Hilo	100	68.4	68.7	69.4	70.8	71.3	72.4	74.0	74.6	73.8	73.0	71.4	69.6	71.4	88	55
Honokaa	470	67.6	67.8	70.1	71.0	72.3	72.6	73.4	74.6	72.8	72.4	71.2	69.0	71.2	90	53
Holualoa	1,350	67.0	66.6	66.7	68.8	68.3	69.4	70.8	71.2	70.8	69.4	68.2	66.2	68.6	84	51
Huehue	2,000	65.2	65.4	66.4	68.3	68.6	70.1	72.6	73.3	71.7	69.8	68.8	66.8	68.9	87	50
Pahala	850	68.6	68.4	68.7	71.2	71.2	72.1	74.0	75.2	74.9	73.0	72.4	72.0	71.8	91	53
Kohala Mill	270	68.4	67.9	69.7	70.9	72.2	72.6	74.2	75.2	74.2	73.1	71.7	70.2	71.7	86	54
Waimea	2,720	58.6	60.4	62.0	61.9	61.9	61.8	63.6	65.1	63.7	64.2	61.7	60.4	62.1	80	44
Volcano House	4,000	57.8	58.6	59.0	59.6	59.2	60.1	60.0	59.2	59.3	61.0	60.8	60.4	59.6	72	42

Biological work has shown that even the lowest monthly means of localities up to 1,500 feet elevation have little effect upon *C. capitata* other than to retard development somewhat. It is never cold enough throughout littoral Hawaii to render either the adults or the larvæ inactive. As a result there are no periods of the year at any Hawaiian port when the climatic conditions are unfavorable for the establishment or increase of this pest. Data presented later in the text indicate that a continuous temperature ranging between 58° and 62° F., or the lowest range of temperature usually experienced in littoral Hawaii, does not increase the normal mortality among the immature stages of the fruit fly, and that these stages withstand for short periods, without injury, temperatures lower than any recorded in Table II. The two stations, Holualoa and Huehue, at about 1,350 and 2,000 feet elevation, respectively, may be taken as fair examples of altitudes above which host fruits are only scatteringly grown, but at which the fruit fly has demonstrated its capacity to injure fruits seriously.

HOST CONDITIONS.

Favorable as are the climatic conditions for the establishment and increase of the Mediterranean fruit fly in Hawaii, the host conditions are even more so. Mr. H. J. Quayle, who has studied fruit-fly conditions throughout southern Europe, and Mr. J. C. Bridwell, who has had similar opportunities in western and southern Africa and in Australia, have stated to the writers that nowhere have they found host conditions so favorable for establishment and rapid increase as in littoral Hawaii, especially about Honolulu and Hilo. Under the subject of host fruits, on page 24, the writers record 72 species of fruits growing in Honolulu that are subject to attack by *C. capitata.* The discussion of their susceptibility to attack, however, throws little light upon their numerical abundance or upon the seasons of the year during which their fruit is available for fruit-fly infestation. During the clean-culture campaign waged against this pest in Honolulu during 1913, data were secured which forcibly demonstrate the ideal host conditions found in Honolulu, making possible extraordinary increase and excessive infestations. The residents of Honolulu are justly proud of their magnificent vegetation and have taken great pleasure in growing an unusually large assortment of trees and shrubs upon their town properties. An inventory of such trees and shrubs, that bear fruits subject to infestation, growing upon 60 blocks in that portion of Honolulu bounded by Liliha, Punchbowl, Beretania, and School streets, is given in Table III.

TABLE III.—*Number of host trees and shrubs of the Mediterranean fruit fly growing during 1913 in that portion of Honolulu bounded by Liliha, Punchbowl, Beretania, and School streets.*

Block.	Lots in block.	Trees in block.	Block.	Lots in block.	Trees in block.	Block.	Lots in block.	Trees in block.	Block.	Lots in block.	Trees in block.
1	19	81	16	18	90	31	7	19	46	9	160
2	10	64	17	6	13	32	10	62	47	4	51
3	10	105	18	5	20	33	5	10	48	15	217
4	3	0	19	23	101	34	5	22	49	23	167
5	16	137	20	12	48	35	5	9	50	6	111
6	9	28	21	18	118	36	8	51	51	16	112
7	9	64	22	7	59	37	14	134	52	9	41
8	4	59	23	3	0	38	13	108	53	5	65
9	6	18	24	14	75	39	41	115	54	14	83
10	9	124	25	3	8	40	12	74	55	23	112
11	28	132	26	7	25	41	36	135	56	26	158
12	6	163	27	4	7	42	17	76	57	12	37
13	9	66	28	4	15	43	18	208	58	4	0
14	9	66	29	9	42	44	24	144	59	3	124
15	25	86	30	2	39	45	9	54	60	12	98

Total number of lots in 60 blocks, 712; total number of trees, 4,610; average number of trees per lot, 6.5; average number of trees per block, 76.8.

From this it will be seen that there was a total of 4,610 trees and shrubs on the 712 lots under consideration, or an average of 6.5 trees per dooryard capable of supporting the fruit fly. In Table IV are given data indicating the relative abundance of different hosts.

TABLE IV.—*Number and species of host trees of the Mediterranean fruit fly growing in that portion of Honolulu covered by Table III.*

Apricot	1	Fig	201	Mandarin	28	Rose apple	25
Avocado	653	Guava, common	94	Mango	1,154	Sapodilla	5
Breadfruit	58	Guava, strawberry	73	Mangosteen	7	Sapota	30
Carambala	48	Java plum	80	Mountain apple	41	Soursop	57
Chinese inkberry	6	Kamani, ball	4	Mock orange	33	Spanish cherry	1
Chinese orange	148	Kamani, winged	13	Orange, sweet	372	Star apple	4
Coffee	298	Kumquat	4	Papaya	687	Surinam cherry	63
Coffee, Liberian	8	Lemon	22	Peach	69	Wi	19
Cotton	11	Lichee	40	Pear, Bartlett	2	Waiawai	60
Custard apple	1	Lime	10	Pomegranate	128		
Damson plum	4	Loquat	33	Pomelo	15	Total	4,610

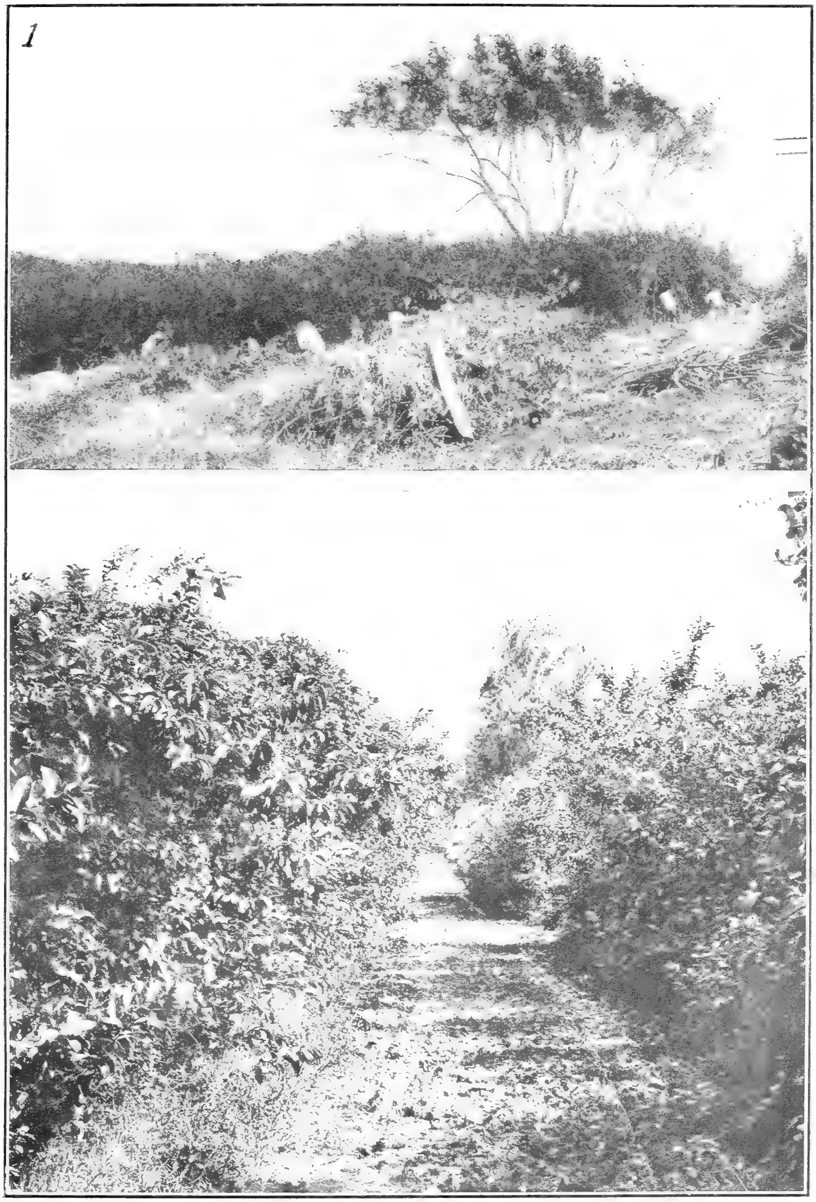
In Hilo, island of Hawaii, host conditions are quite as favorable for fruit-fly development as in Honolulu. Thus the following numbers of host trees and shrubs were found in certain yards of Hilo during March, 1914:

YARD 1.	YARD 2.	YARD 3.	YARD 4.
1 Rose apple.[1]	2 Surinam cherry.	11 Rose apple.	4 Peach.
4 Surinam cherry.	2 Papaya.	2 Mango.	6 Mango.
2 Japanese plum	1 Thevetia.	3 Thevetia.	1 Loquat.
6 Mountain apple.	2 Orange.	1 Avocado.	3 Winged kamani.
1 Star apple.	2 Strawberry guava.		2 Surinam cherry.
34 Coffee trees.	14 Coffee.		1 Strawberry guava.
20 Common guava.	Bananas.		
15 Brazilian banana.	2 Avocado.		
4 Avocado.	1 Peach.		
3 Mango	3 Fig.		
2 Papaya.	2 Mountain apple.		
5 Orange	2 Lichee nut.		
1 Peach.	3 Common guava.		
1 Grape.			
1 Winged kamani.			
1 Mangosteen.			
1 Fig.			
1 Mimusops.			

There is no time in Hawaii when fruits are entirely out of season. The fact that several hosts, such as the Chinese orange (*Citrus japonica*), Surinam cherry (*Eugenia michelii*), and mock orange (*Murraya exotica*), bear several crops a year, while others, such as certain specimens of ball kamani (*Calophyllum inophyllum*) (Pl. VI) and winged kamani (*Terminalia catappa*) (Pl. XIX), appear to be seldom entirely free from ripening fruits, assures food for the fruit fly the year round.

The succession of fruits is also increased by the individuality of trees of the same species, or even of certain branches of a single tree, which results in a very uneven ripening of the fruit. While the data in Table V do not indicate the seasonal abundance of host fruits, they have been summarized from the collections of clean-culture inspectors made during 1913 to show the remarkable succession of host fruits found ripening in greater or less quantities throughout

[1] For scientific names of fruits see section on host fruits, p. 24.

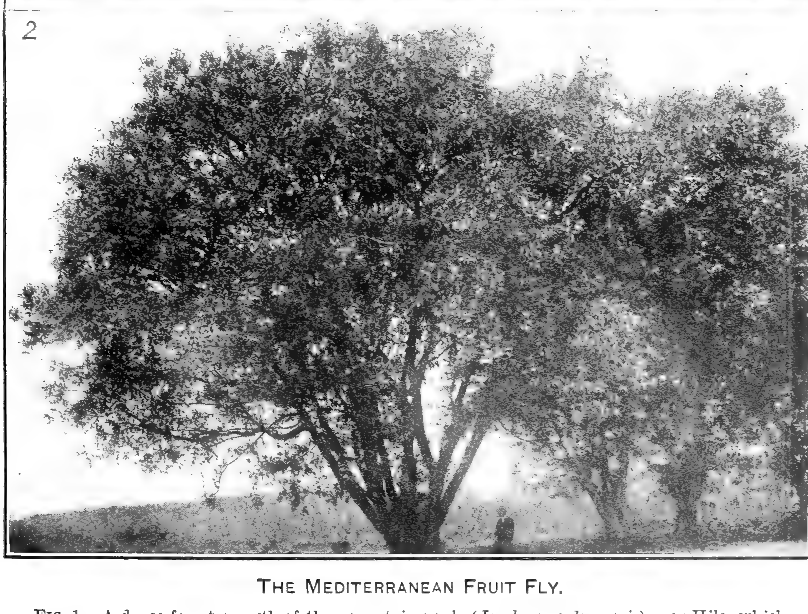


RELATION OF FLORA OF HAWAIIAN ISLANDS TO THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—Men grubbing out a guava scrub which has taken possession of pasture land. Many thousands of acres are thus overrun in Hawaii and furnish excellent breeding grounds for the fruit fly. The ripening fruits fall into the dense grass and the larvæ within them develop unmolested by the heat of the sun. FIG. 2.—Thickets of guava bushes often crowd upon the country roads and ripen tons of fruit. This fruit is gathered by pedestrians and autoists and carried to all parts of the islands, thus becoming a medium for the wide dissemination of the pest. (Original.)

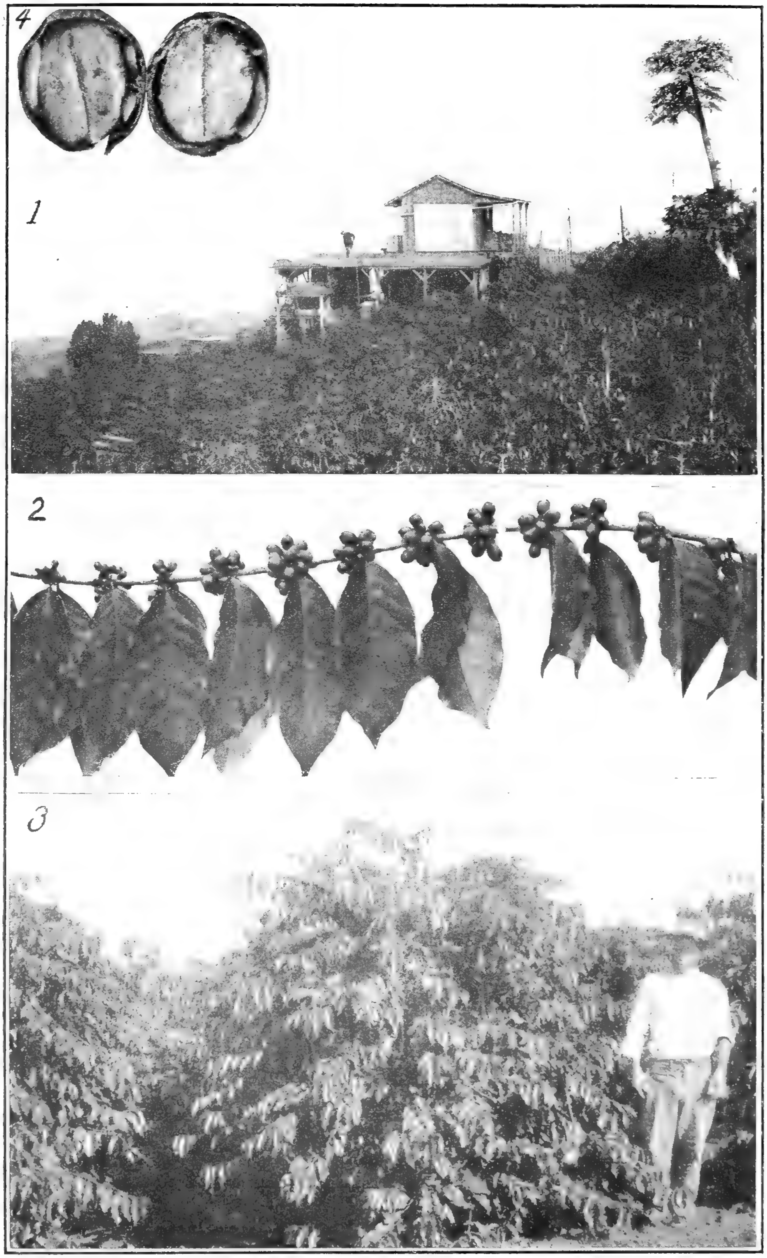
RELATION OF THE FLORA OF THE HAWAIIAN ISLANDS TO THE MEDITERRANEAN FRUIT FLY.

It is difficult to find in Hawaii cultivated fields of any crop that are not closely surrounded by wild hosts of the fruit fly. In the above illustration, between the pineapple field in the foreground and the ocean, are growing, at the right and left, dense thickets of guava, while in the center are many large Terminalia trees. In such places the fruit fly finds, in the ripening fruits of these hosts, food for its support throughout the entire year. Throughout the precipitous and gullied mountains in the background the fruit fly is thoroughly entrenched in wild host fruits. (Original.)



THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—A dense forest growth of the mountain apple (*Jambosa malaccensis*) near Hilo, which illustrates one of the many strongholds in Hawaii that the fruit fly found favorable to its thorough entrenchment. FIG. 2.—Rose apple trees (*Eugenia jambos*). While the fruit of this tree ripens chiefly during the months of March to May, a few may be found beneath trees at any time. Fruits of both the mountain apple and the rose apple are among a class of host fruits that are carelessly taken on board ships by tourists, in whose possession they have been intercepted by the officers of the Federal Horticultural Board at San Francisco. (Original.)



THE MEDITERRANEAN FRUIT FLY AND THE COFFEE INDUSTRY.

FIG. 1.—Coffee plantation on the Kona slopes of Hawaii. FIG. 2.—A fruiting branch. FIG. 3.—Low type of coffee tree. FIG. 4.—Coffee cherry cut to show the two large beans which are of commercial value, and the very thin outer pulp. This pulp is the only portion of the cherry eaten by the fruit-fly larvæ. Note that the well-grown larvæ illustrated feed so close to the papery epidermis that parasites have no difficulty in ovipositing in them. Thousands of acres are densely planted to coffee on the island of Hawaii and offer food for the fruit fly the year round. (Original.)

the year in Honolulu. The presence of so much ripening fruit, coupled with the favorable climatic conditions and the hardiness of the fruit fly itself, has made the establishment of *C. capitata* and its multiplication a most easy problem within the city limits.

While the fruit fly finds host conditions most favorable within the city limits, because of the large number of host trees and shrubs, some of which are bearing at all seasons of the year, it has been able to establish itself and multiply in the country, often miles from towns, in some one or more of its hosts which have escaped cultivation, and to have spread over uncultivated and uncultivable areas. Of such hosts, the common guava (*Psidium guayava*) is the most abundant. It has taken possession of the roadsides, pastures (Pl. II), vacant town lots, mountain gulches and hillsides, and even crevices in precipices, from sea level up to 1,500 feet elevation.[1] So easily does this plant grow from seed, and so thoroughly distributed are its seeds by cattle, birds, and man, that it is seldom that a bush can not be found within a stone's throw. In the lowland pastures and mountain gulches up to an elevation of at least 1,300 feet, particularly when sheltered from strong winds and well watered, the guava may become very treelike and form dense thickets (Pl. III). At higher altitudes, and in wind-swept or arid areas, it may remain a low, scrubby bush. While the guava fruits most heavily during the spring and fall months, the bushes are continually blooming and ripening a sufficient number of fruits to support the fruit fly every month in the year. The writers are depending upon the illustrations to acquaint the reader, as words can not, with the well-nigh universal distribution of this host and the wonderful opportunities it offers *C. capitata* for easy establishment and thorough intrenchment.

Second to the guava as a host occurring in wild, uncultivated areas is the prickly-pear cactus (*Opuntia vulgaris*) (Pl. XVII). While the fruits of this plant are not preferred by the Mediterranean fruit fly, they are sufficiently infested in the absence of more favored hosts to serve as food, and, as in the case of the guava, there is almost no time during the year when a few ripe fruits may not be found in any cactus scrub.

Other host fruits, wild or escaped, are not so universally distributed. As a few of the many examples, there may be mentioned a grove of ball kamani trees in an isolated valley on the island of Molokai, gulches overgrown with the passion vine (*Passiflora* sp.) and the damson plum (*Chrysophyllum oliviforme*) on the island of Maui, the thickets of winged kamani growing along the windward shores of the island of Oahu, and the wild coffee and mountain apple (Pl. IV, fig. 1) in the forests of Oahu and Hawaii.

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[1] Stunted bushes have been observed at 4,000 feet elevation.

TABLE V.—*Data indicating the seasons of the year when inspectors of the clean-culture campaign in Honolulu collected various fruits infested by the Mediterranean fruit fly.*[1]

Host.	Jan. 1-11.	Jan. 13-18.	Jan. 20-25.	Jan. 27-Feb. 1.	Feb. 3-8.	Feb. 10-15.	Feb. 17-22.	Feb. 24-Mar. 1.	Mar. 3-8.	Mar. 10-15.	Mar. 17-22.	Mar. 24-29.	Mar. 31-Apr. 5.	Apr. 7-12.	Apr. 14-19.	Apr. 21-26.	Apr. 28-May 3.	May 5-10.	May 12-17.	May 19-24.	May 26-31.	June 2-7.	June 9-14.	June 16-21.	June 23-28.	June 30-July 5.
Avocado	...	...	...	x	...	...	...	x	...	...	...	...	x	...	...	...	...	...	...	x	...	...	...	...	...	x
Carambola	x	x	x	x	x	x	x	x	x	x	x	x	...	x	x	...	x	...	...	...	...	...	...	...	...	...
Chinese orange	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Chrysophyllum spp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Coffee	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Damson plum	x	x	x	x	x	x	x	x	x	x	...	...	...	...	x	x	x	x	x	x	x	...	...	...	...	...
Surinam cherry	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Fig	x	x	x	x	...	x	x	x	x	x	x	x	x	x	x	x	x	x	x	...	x	x	...	...	...	...
Grapefruit	x	x	x	x	x	x	...	x	x	x	x	x	...	x	...	...	...	x	x	...	...	x	...	...	...	...
Guava	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Kamani, ball	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Kumquat	...	x	x	x	...	x	x	...	...	...	x	...	...	x	...	...	x	x	x	...	...	x	...	...	...	...
Lime	x	x	x	x	x	x	x	x	x	x	...	x	x	...	x	x	...	...	...	x	...	x	x	x	...	x
Loquat	x	x	x	x	x	x	x	x	x	x	x	...	x	x	...	x	x	...	...	x	x	...	...	...	...	...
Mango	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Mock orange	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	...	x	x	x	x	...	x	...
Mountain apple	...	...	x	x	x	...	x	x	...	x	...	...	...	...	x	x	x	x	x	x	x	x	...	...	x	...
Orange	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Papaya	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Peach	...	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Pepper	x	x	x	...	x	x	x	x	x	x	x	x	x	x	...	...	...	...	...	...	...	...	...	...	...	...
Prickly pear	...	...	x	...	...	x	...	...	...	...	...	...	x	...	...	x	...	...	x	...	...	...	...	...	x	x
Rose apple	...	x	...	x	x	x	x	x	x	x	x	x	...	x	x	x	x	x	x	x	x	x	x	x	x	x
Star apple	...	...	...	...	...	...	...	...	x	x	x	x	x	...	x	...	x	x	x	...	x	x	...	...	...	...
Bestill	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Soursop	...	...	...	x	x	x	x	x	...	x	x	x	x	x	x	x	x	x	x	x	...	x	x	x	x	x
Mandarin	x	x	x	x	x	x	x	x	x	x	x	...	x	x	x	x	x	x	x	x	...	...	...	...	x	...
Lemon	x	x	...	x	...	x	...	x	x	x	x	x	...	x	x	x	x	x	x	x	x	x	x	x	x	x
Kamani, winged	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Spanish cherry	...	x	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	x	x	x	x
Bartlett pear	...	...	...	...	...	...	...	...	...	...	...	x	x	x	...	...	...	...	...	...	...	...	...	...	x	...

Host.	July 7-12.	July 14-19.	July 21-26.	July 28-Aug. 2.	Aug. 4-9.	Aug. 11-16.	Aug. 18-23.	Aug. 25-30.	Sept. 1-6.	Sept. 8-13.	Sept. 15-20.	Sept. 22-27.	Sept. 29-Oct. 4.	Oct. 6-11.	Oct. 13-18.	Oct. 20-25.	Oct. 27-Nov. 1.	Nov. 1-9.	Nov. 11-16.	Nov. 18-23.	Nov. 25-30.	Dec. 2-7.	Dec. 9-14.	Dec. 16-21.	Dec. 23-31.
Avocado	x	x	x	x	x	x	x	x	x	x	x	x	x	...	...	x	...	...	...	...	...	x	x	x	x
Carambola	...	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Chinese orange	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Chrysophyllum spp.	...	...	...	...	...	x	x	...	...	x	x	...	x	...	...	x	...	...	...	...	...	...	...	...	...
Coffee	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Damson plum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Surinam cherry	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Fig	x	x	...	x	...	x	x	...	x	x	...	x	...	x	...	...	...	x	...	x	x	x	x	...	x
Grapefruit	...	...	...	x	...	...	x	...	...	...	...	...	x	x	...	x	x	x	x	...	x	x	x	x	x
Guava	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Kamani, ball	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Kumquat	...	...	...	...	x	...	x	x	...	x	x	x	x	x	x	x	x	...	...	...	x	x	...	...	x
Lime	x	...	x	x	x	x	x	x	...	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Loquat	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	x	x	x	x	x	x	x
Mango	x	x	x	x	x	x	...	...	x	...	...	...	...	...	...	...	x	x	x	x	...	x	x	x	x
Mock orange	x	x	...	x	...	x	x	x	x	x	...	x	x	x	x	x	x	x	x	x	...	x	x	x	x
Mountain apple	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	x	...	x	...	...	x
Orange	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Papaya	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Peach	...	x	x	x	...	x	...	...	x	...	...	...	x	...	...	...	...	x	...	...	...	...	...	...	x
Pepper	...	x	...	...	x	...	...	...	x	x	...	x	...	...	...	x	x	x	x	x	x	x	x	x	x
Prickly pear	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	...	...	...	...	...	x	x	x	x
Rose apple	x	x	x	x	...	x	x	...	...	...	...	x	x	...	x	x	...	...	...	...	...	...	...	x	x
Star apple	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...
Bestill	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Soursop	x	x	...	x	x	x	x	x	x	x	x	x	x	x	x	x	x	...	...	...	x	...	x	...	x
Mandarin	x	...	x	x	...	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lemon	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Kamani, winged	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Spanish cherry	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	...	...	...	x	x	x
Bartlett pear	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

[1] This table is not intended to indicate the seasonal abundance of host fruits.

In addition to the wild fruits in country places, the fruit fly finds strongholds in the many, and often very isolated, native-home sites scattered throughout the littoral regions. About these may be growing the mango (Pl. XII), rose apple (Pl. IV, fig. 2), orange, peach, avocado, ball and winged kamanis, etc. In the Kona district of the island of Hawaii there are large areas containing thousands of acres of coffee under cultivation (Pl. V) in which the fruit fly finds food in the pulp of the ripening cherries at all seasons of the year because of the irregularity in blooming and the long harvesting season due to the varying altitudes at which coffee is grown.

ECONOMIC IMPORTANCE.

The economic importance of the Mediterranean fruit fly as a pest of fruits varies with the climate of its habitat. Thus in France, near Paris, where it has been known to attack apricots, pears, and peaches, it has not become a serious pest because of climatic checks, and such checks to the severity of its attack have been noted in portions of Australia and South Africa and would be operative in continental United States, except in parts of California and of the Southern States. On the other hand, in tropical and semitropical climates this fruit fly is capable of becoming a pest of prime importance and, as in the Hawaiian Islands, may be classed as the most important insect check to horticultural development. A study of the fruits infested by this world-wide pest shows that practically every fruit crop of value to man is subject to attack. Not only is the Mediterranean fruit fly of importance as a destroyer of fruit, but it is the cause of numerous stringent quarantines which cost the State and Federal governments much money to make effective, and rob countries of good or prospective markets for their fruit. Fortunately it has been found that the Chinese banana (*Musa cavendishii*) and the pineapple (*Ananas sativus*), the two most valuable species of fresh fruits formerly exported from Hawaii, offer so little danger as carriers of the Mediterranean fruit fly when they are packed for shipment that this part of Hawaii's export trade with the coast may still be carried on, provided the inspections of the Federal Horticultural Board now in force are continued. The necessary quarantine against all other host fruits, however, particularly against such fruits as the avocado and mango, two fruits which can be grown very well in Hawaii, has had, and will continue to have, a serious effect upon horticultural pursuits and the development of the small farmer.

At the present time the infestation of edible fruits in littoral Hawaii is general and about as severe as could be expected. Aided by the melon fly (*Bactrocera cucurbitae* Coq.), the Mediterranean fruit fly has effected a most serious and permanent check upon the horticultural development of the Hawaiian Islands unless a successful

method for combating it is developed. In the Bermuda Islands the peach industry has been a ruined one for many years. MacLeay and Westwood wrote, during the early part of the nineteenth century, of the increased cost to the inhabitants of London of citrus fruits imported from the Azores as a result of fruit-fly attack. Lounsbury and Mally, of South Africa, consider *C. capitata* one of the greatest drawbacks to the development of the fruit industry in Cape Colony, and have stated that during certain favorable seasons large areas of apricots, figs, pears, plums, apples, and quinces were almost all affected. Hooper, writing from Southern France, states in 1904 that, as a result of fruit-fly attack, what was once an important and lucrative industry was at that time little more than a haphazard traffic in fruit casually produced. In 1903 Compere found that peach growing about Barcelona, Spain, had been so demoralized by fruit-fly attack that few trees were being grown and that the market was supplied by fruit from the Balearic Islands, while at Cadiz the fruit merchants no longer cared to handle peaches owing to the fact that they were badly infested. At Malaga, according to Compere, the bitter Seville oranges are seriously affected. Wickens, writing in 1913 in Western Australia, states that the fruit industry there was suffering not only directly as a result of the actual loss of fruit infested, but indirectly through the restricted plantings in districts where the fruit fly was abundant. About Perth, where late peaches can be grown to perfection, very few are being cultivated; instead, many trees have been cut down. Other instances of damage caused to citrus crops in southern Europe, South America, Africa, and Australia might be added which would impress one, unfamiliar with the ravages of *C. capitata*, that it is a very serious pest. Its economic importance is so great that every effort should be taken to prevent its establishment in new territory.

INJURY.

NATURE OF INJURY.

The injury caused by the Mediterranean fruit fly is confined to the fruits of the hosts attacked. The foliage, stems, and roots are not attacked so far as investigators have been able to determine. No better idea of the nature of the injury caused by the fruit fly can be gained than from an examination of the illustrations. The larvæ hatching from the eggs deposited just beneath the epidermis burrow their way throughout the pulp and, as they develop, cause by their feeding, and through the development of fungi and bacteria, decayed areas which vary in extent according to the age and number of the larvæ and the ripeness of the host. Since the larvæ most frequently burrow at once to the pit or core of the fruit, they are able to feed for some time before their work is evident from the surface; thus peaches and

oranges may be quite thoroughly devoured within and yet maintain a fairly normal appearance externally. In rapidly growing fruits, or those oviposited in while they are still too green to support larval growth, slight deformities are developed which injure the appearance of the fruit. In lemons, oranges, and grapefruit which have been provided so well by nature to withstand fruit-fly attack, the rind may become badly infested with eggs and young larvæ, while the pulp remains edible. The breaks in the skin made by the female fly in depositing eggs, however, affect the shipping qualities of such citrus fruits and, from this commercial aspect, may cause an injury the nature of which is quite as serious as is any to the pulp.

EXTERNAL EVIDENCES OF INJURY.

There are always external evidences of infestation, but these are often so inconspicuous that they are overlooked by the average person. The eggs are deposited by the adult through a break, no larger than a pin prick, made in the skin. While these punctures are readily discernible under the hand lens as soon as made, there is nothing about them to attract attention. Soon after oviposition, however, the tissues about the egg cavity begin to wither and there develops about the puncture a discolored or sunken area in the skin. In certain hosts the immediate area about the puncture may remain green long after the remainder of the fruit has turned yellow, as in the loquat (*Eriobotrya japonica*), or red, as in the strawberry guava (*Psidium cattleyanum*). In green oranges the fruit may turn yellow about the puncture while the rest of the fruit remains green. Such tender-fleshed fruits as the ripening Surinam cherry (*Eugenia michelii*) may develop sunken areas without discolorations. Often filaments of clear gummy excretions exude from punctures made in peaches, lemons, and grapefruit. Punctures made in green star apples (*Chrysophyllum cainito*) are usually marked by exuding white latex which dries about and over the puncture. Punctures made in quite green winged kamani nuts (*Terminalia catappa*), in which no development of larvæ occurs, are marked by depressions in the flesh due to permanently arrested development at the punctured point. Oviposition or attempted oviposition in bananas and partially ripe mangoes is followed by exudations which run down the sides of the fruit and dry as a dark stain. The evidences of early infestation such as have just been mentioned are too numerous to warrant description. No one host responds to infestation exactly the same each time; much depends on the degree of ripeness at the time of attack. There may be no gummy exudations from peaches or citrus fruits, and there may be no development of discolored areas in any of the host fruits. Avocados seldom give evidence of infestation by any external mark except the puncture in the skin. Fruits already

ripened when infested show none of the usual signs of attack ur the larvæ have begun to work. It is due to this failure of fruit record their infestation by some external sign, other than the i spicuous puncture, that so much fruit is purchased as sound markets, or shipped from orchards, or taken on board ships

As the larvæ hatch and begin their work of destruction v host, the signs of infestation increase rapidly. The sunk about the punctures of tender-fleshed fruits may increase until the entire fruit has a collapsed appearance.

In all fruits well infested within there is a "give" to the area beneath the puncture, indicating destroyed tissues beneath. In hard-fleshed fruits such as some varieties of apples (Pl. XI, fig. 2), pears, and quinces there may be no external evidence of larval work except a ring of dark decay about the puncture, and yet the outer portion of the pulp alone may be unaffected. Peaches are often thoroughly infested within and still maintain their normal shape and give evidence of infestation only by a dull and slightly darkened color of the skin. A hole in the rind, no larger than the lead of a pencil, from which juice exudes when the fruit is compressed, may be the only indication of infestation in oranges and grapefruit, although rings of decay usually develop in infested citrus fruits containing numerous larvæ. Fruits of the elengi tree (*Mimusops elengi*), which have an orange shell-like exterior (Pl. VIII, fig. 2), may appear normal, but on being broken open are found to be literally packed with well-grown larvæ. It is never possible for the average man to examine casually any host fruit and state conclusively that it is not infested.

METHODS OF SPREAD.

There are numerous records on file which demonstrate clearly the methods by which the Mediterranean fruit fly is spread, not only between widely separated countries, but about land areas. The development of rapid transit and cold storage and the increase in tourist travel have been the greatest factors in dissemination in more recent times. Geographical isolation is no longer a protection against introduction, as has been proved almost monthly by the interception of fruit flies at the ports of entry of the United States by the agents of the Federal Horticultural Board.

SHIPS.

The unrestricted consignments of fruit and ships' stores have been responsible for much of the spread of *C. capitata* between countries. MacLeay, as early as 1829, records the importation at London of cargoes of oranges from the Azores that contained larvæ, and Middleton, in 1914, states that in the same city hundreds of larvæ and pupæ are imported every year from Spain and destroyed

in the manufacture of marmalade. The establishment of *C. capitata* in both the eastern and western parts of the Australian continent is traceable to the development of cold storage and rapid ocean transportation which made possible the large exports of citrus fruits from the Mediterranean region to Australia. Kirk records the receipt at Auckland, New Zealand, of a case of peaches from Cape Colony which contained living larvæ, although they had been en route in cool storage for four weeks. The same writer intercepted 47 cases of infested apples at Wellington, New Zealand, imported from New South Wales. Lea, in 1908, states that larvæ of *C. capitata* were seen in numbers every year in fruit imported into Tasmania from Sydney. The establishment of this pest in the Bermudas and South America is beyond doubt the result of the importation of infested fruit from Mediterranean regions. Increased knowledge of fruit flies and the quarantines in force in several countries now make the introduction of this pest in consignments of fruits less likely.

The vigilant work of the quarantine officials at the Pacific ports of the United States, however, demonstrates the grave danger that still exists of introducing the Mediterranean fruit fly in ships' stores. Instances of the discovery and destruction of the pest in fruits in ships' stores on vessels entering the port of San Francisco during the past four years are recorded in the reports of Frederick Maskew, chief quarantine officer of the California Horticultural Commission and collaborator of the Federal Horticultural Board.

TOURISTS.

The desire on the part of tourists to carry to their friends at home specimens of exotic fruits is at the present time the most likely avenue for the introduction of this fruit fly into California as well as the southern United States. This has been clearly proved not only by the large variety of host fruits offered for inspection at Honolulu, but by the interceptions at the California ports. To the quarantine officer the tourist is a difficult problem. Fruits carried in containers are easily observed, but smaller fruits are found with difficulty. Strong, in 1913, discovered in the overcoat pocket of a tourist landing at San Francisco infested nuts of the winged kamani (*Terminalia catappa*), which were intended for planting in southern California. In like manner infested coffee cherries were found at Honolulu in the pocket of a gentleman about to sail during February, 1916, from Honolulu direct to San Pedro, Cal.

DISSEMINATION ON LAND BY PUBLIC AND PRIVATE CONVEYANCES.

On land, railroads, automobiles, hawkers' carts, carriages, etc., are all responsible for much spread. The fact that host fruits only slightly infested appear normal to the average man leads to the pur-

chase by the traveling public of much fruit which later, when found to be infested, is discarded, often many miles from the point of origin. Bairstow as long ago as 1893 records the selling of infested apricots by native girls to passengers on trains about to leave for interior points of South Africa. The spread of the pest in Australia has been most rapid along the railroads. French, in 1896, states that peaches imported by rail into Victoria from Sydney were infested and Newman states that in Western Australia many instances have come under his observation in which infested fruits thrown from the windows of coaches of both suburban and country trains were responsible for introductions into districts previously free from attack.

In the Hawaiian Islands the spread from village to village and from island to island unquestionably has been hastened by the habit of the poorer population of carrying small lots of fruit in their travels, either for food while en route or as presents for their friends. Much of this fruit is more or less infested, and when an attempt to eat it proves the interior to be infested and unpalatable, it is discarded either along the road or at the point of destination. The inspection service of the Hawaiian Board of Agriculture has shown that even the most stringent regulations have not prevented the movement of infested fruits from point to point by man in automobiles, in carriages, or on foot.

POSTAL AND EXPRESS PACKAGES.

The interception at Washington, D. C., by officers of the Federal Horticultural Board of a package from Mexico containing a living pupa of the papaya fruit fly (*Toxotrypana curvicauda* Gerst.) attached to an unknown vine, and of a living adult of the olive fruit fly (*Dacus oleae* Rossi) and a dead adult of another species of fruit fly, apparently *Dacus semispharens* Becker, in a package of olive seed, 28 days after it had been mailed in South Africa, indicates the possibilities for spread by means of parcel post. The persistency with which uninformed persons insist upon including among bananas and pineapples intended for shipment by express from Hawaii to the mainland United States small contraband host fruits has demonstrated fully the danger of express packages as carriers of *C. capitata*.

NURSERY STOCK.

A fruit-fly pupa (species unknown) was found at Auckland, New Zealand, in the soil about the roots of a plant imported from Australia. Newman has called attention to the danger of spreading the fruit fly in the pupa stage, in the soil about the roots of nursery stock grown beneath host fruit trees.

PACKING MATERIALS.

Larvæ developing in fruits packed in wooden crates or in bags often pupate against the sides of such containers. Second-hand

packing crates and old burlap, etc., recently used as containers are apt to carry the pest and should be guarded against until experience for the locality and temperature concerned has proved that the adults have emerged. Certain instances of spread in western Australia are believed to have occurred through carelessness in the use of second-hand packing cases. In Hawaii, Hilo grass (*Paspalum conjugatum*), gathered from beneath guava bushes (Pl. XIV, fig. 1, insert), was discontinued as a packing material for bananas for fear pupæ of the fruit fly attached to it might reach California.

COLD STORAGE.

While cold-storage temperatures may be used to render fruits free from danger as transporters of the fruit fly (see p. 108), the use of temperatures fluctuating above 38° F. may be one of the greatest aids in prolonging the duration of fruit-fly life within host fruits.

WIND.

That adult males of the Mediterranean fruit fly can be carried by the wind distances varying from one-fourth to 1½ miles from points of liberation has been demonstrated by Severin, who states further that in all probability some of the flies which he had set free at the head of Manoa Valley "were caught up and carried far into the city of Honolulu, or even away beyond into the sea, miles away from the points of liberation." The writers agree with Severin as to the ability of winds to carry adults considerable distances. The discovery by Mr. H. T. Osborn of an adult upon the summit of Konahuanui (elevation 3,105 feet), the highest peak of the range separating the windward and leeward sides of the island of Oahu, and at a considerable distance above the highest range of host plants, makes it easier for the writers to believe that the few adults which they captured in traps in the scant vegetation on the leeward shore line, and at considerable distances from known sources of infestation, during very windy weather, were specimens caught on the windward side in strong ascending air currents and carried entirely across Oahu. There is no doubt that the adult on Konahuanui observed by Osborn was transported thus from the lower windward levels.

HOST FRUITS.

The writers know of no edible fruit commonly grown in the Hawaiian Islands, except the pineapple, that is not subject to attack by the Mediterranean fruit fly. From a practical trade standpoint the banana should not be considered a host when grown and shipped in accordance with the regulations of the Federal Horticultural Board.

FRUITS ERRONEOUSLY LISTED AS HOSTS.

No infestation has been found in pineapples (*Ananas sativus*), banyan (*Ficus indica*), pride of India or chinaberry (*Melia azedarach*), noni (*Morinda citrifolia*), jujube (*Zizyphus jujuba*), mulberry (*Morus nigra*), tamarind pods (*Tamarindus indica*), wine palm (*Caryota ureus*), *Ixora coccinea*, *Canarium commune*, *Sideroxylon sandwichensis*, mammee apple (*Mammea americana*), durion (*Durio zibethinus*), Cape gooseberry or poha (*Physalis peruviana*), ohelo berry (*Vaccinium reticulatum*), kukui nut or candlenut tree (*Aleurites moluccana*), night-blooming cereus (*Cereus triangularis*), and jack fruit (*Artocarpus integrifolia*).

PINEAPPLE.

The pineapple (*Ananas sativus*) is not a host fruit of the Mediterranean fruit fly in Hawaii. Negative data are given here because of the persistent reports that this fruit is subject to fruit-fly attack. Illingsworth reared the pineapple fruit fly (*Dacus xanthodes* Broun) from pineapples in Fiji in 1913. In 1904 Kirk states that he had reared only the Queensland fruit fly (*Dacus tryoni* Frogg.) from pineapples exported from Queensland into New Zealand. In 1908 Kirk again states that *Dacus xanthodes* was commonly found in pineapples and oranges from Fiji and Rarotonga entering New Zealand. Gowdey, in 1913, reports rearing *C. capitata* from pineapples in Uganda, British East Africa. So far as the writers are aware no data have ever been published from careful experiments to determine the true status of the pineapple as a host fruit, and the writers know of no positive evidence that *C. capitata* has ever been reared from this fruit.

It is certain that during a period of over three years not one of seven entomologists in Honolulu has succeeded in rearing adults from this fruit. Fullaway, of the United States Experiment Station, obtained negative results from fruits placed in a large cage. The market and plantation inspectors of the Federal Horticultural Board have brought to the office during the past three years many partially decayed fruits, but no fruit flies were reared from them, although many decay flies were. Although pineapples are grown profitably only under the best horticultural conditions (Pl. III), none of the developing fruits are sufficiently isolated from other varieties of host fruits affected to warrant the belief that adult fruit flies are not present in large enough numbers to infest each fruit were the pineapple susceptible to infestation.

In an attempt to force an infestation within the laboratory, 50 ripe pineapples were placed either singly or by twos in large glass jars containing from 300 to 500 adult flies in a mature egg-laying condition, and allowed to remain with the flies from 2 to 4 days. The pineapples were then removed and placed over sand in covered jars. No flies

were reared from the fruits. The flies readily deposited eggs in apples placed with them both before and after exposure of the pineapples. A record of the time each of the 50 fruits was exposed is as follows:

TABLE VI.—*Nonsusceptibility of pineapples to the attack of the Mediterranean fruit fly.*

Number of fruits exposed.	Dates of exposure to infestation.	Number of fruit flies reared.
	1913.	
2	Oct. 14–15	None.
1	Oct. 17–18	
1	Oct. 19–22	
2	Oct. 23–24	
6	Oct. 27–29	
10	Oct. 30–Nov. 2	
12	Nov. 5–7	
16	Nov. 9–11	

During July 18–20, 1913, a very ripe pineapple was hung in a jar containing flies. An examination of the fruit after this two-day exposure revealed 2 punctures in the pulp containing respectively 16 and 11 eggs. One puncture had been made in a slight abrasion; the other in normal tissue between the eyes. Seven other batches of eggs, containing 9, 5, 8, 7, 4, 5, and 4 eggs, respectively, had been deposited on the surface of the fruit, but in the creases between the eyes.

In experimental work the writers have had no difficulty in transferring larvæ from one favored host fruit to another. Experiments in transferring first, second, and third stage larvæ to pineapple invariably resulted in the death of the larva. A total of 925 larvæ were transferred, as follows:

TABLE VII.—*Failure of larvæ of the Mediterranean fruit fly to develop in the pulp of ripe pineapples.*

Date of transfer.	Number larvæ transferred.	Instar when transferred.	Results.
Apr. 22	150	Second	All died by Apr. 26.
Apr. 23	200	....do	Do.
Apr. 22	100	First	All died by Apr. 24.
Do	25	Second	19 dead by Apr. 25; 6 dead by Apr. 26.
Do	150	Young third	All dead by Apr. 25.
Apr. 23	150	....do	Do.
Apr. 22	150	Well grown third	Do.

While the experiments above reported indicate that under forced laboratory conditions a few eggs may be deposited within the pulp of very ripe pineapples, the failure of all stages of the larvæ to survive in a medium of fresh ripe pineapple pulp is conclusive evidence that the pineapple should be dropped from lists of host fruits of the Mediterranean fruit fly.

PROVEN HOSTS IN HAWAII.

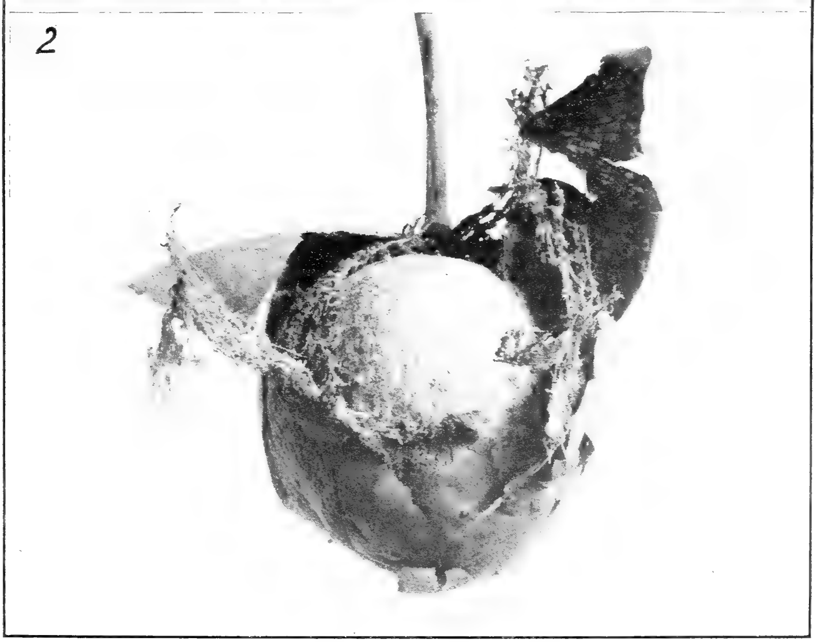
Adults of the Mediterranean fruit fly have been reared from the fruits of the trees, shrubs, and vegetables in the following list. The hosts are arranged alphabetically according to scientific name, and not according to the preferences shown by the fruit fly. The numbers in parentheses refer to the degree of preference for each fruit as a host. Fruits that are heavily or generally infested are marked (1), those that serve occasionally as hosts or of which many escape infestation are marked (2), while those rarely infested are marked (3). The writers appreciate that differences of opinion may arise over any classification of hosts according to degree of infestation, and realize that in colder climates than Hawaii some of the fruits classed as (2) would fall into class 3, or even might not be recorded as hosts at all. The list following represents conditions in littoral Hawaii, particularly about Honolulu:

Hosts of Mediterranean fruit fly in Hawaii.

Scientific name.	Common name.
1. *Achras sapota* (3)	Sapodilla.
2. *Acordia* sp. (3)	Acordia.
3. *Anona muricata* (2)	Sour sop.
4. *Arenga saccharifera* (3)	Sugar palm.
5. *Artocarpus incisa* (3)	Breadfruit.
6. *Averrhoa carambola* (2)	Carambola.
7. *Calophyllum inophyllum* (1)	Ball kamani.
8. *Capsicum annuum* var. *grossum* (2).	Bell pepper.
9. *Carica papaya* (2)	Papaya.
10. *Carica quercifolia* (2)	Dwarf papaya.
11. *Carissa arduina* (2)	Carissa.
12. *Casimiroa edulis* (1)	Sapota.
13. *Cestrum* sp. (3)	Chinese inkberry.
14. *Chrysophyllum cainito* (1)	Star apple.
15. *Chrysophyllum oliviforme* (1).	Damson plum.
16. *Chrysophyllum polynecium* (1).	
17. *Citrus japonica* (1)	Chinese orange.
18. *Citrus japonica* (1)	Kumquat.
19. *Citrus nobilis* (1)	Tangerine.
20. *Citrus nobilis* (1)	Mandarin.
21. *Citrus medica limetta* (1)	Lime.
22. *Citrus medica limonum* (1)	Lemon.
23. *Citrus decumana* (1)	Grapefruit.
24. *Citrus decumana* (1)	Shaddock.
25. *Citrus aurantium* (1)	Orange.
26. *Citrus aurantium* var. *amara* (1).	Sour orange.
27. *Clausena wampi* (3)	Wampi.
28. *Coffea arabica* (1)	Coffee.
29. *Coffea liberica* (1)	Liberian coffee.
30. *Cydonia vulgaris* (1)	Quince.
31. *Diospyros decandra* (1)	Persimmon.
32. *Eriobotrya japonica* (1)	Loquat.
33. *Eugenia brasiliensis* (1)	Brazilian plum or Spanish cherry.
34. *Eugenia jambos* (1)	Rose apple.
35. *Eugenia michelii* (1)	Surinam cherry.
36. *Eugenia uniflora* (1)	French cherry.
37. *Ficus carica* (1)	Fig.
38. *Garcinia mangostana* (2)	Mangosteen.
39. *Garcinia xanthochymus* (2)	Mangosteen.
40. *Gossypium* spp. (2)	Cultivated cotton.
41. *Jambosa malaccensis* (2)	Mountain apple.
42. *Latania löddigesii* (3)	Blue palm.
43. *Lycopersicum esculentum* (2).	Tomato.
44. *Litchi chinensis* (3)	Lichee nut.
45. *Mangifera indica* (1)	Mango.
46. *Mimusops elengi* (1)	Elengi tree.
47. *Murraya exotica* (1)	Mock orange.
48. *Musa* spp. (3)	Banana.
49. *Noronhia emarginata* (3)	Noronhia.
50. *Ochrosia elliptica* (2)	Ochrosia.
51. *Opuntia vulgaris* (2)	Prickly pear.
52. *Passiflora coerulea* (3)	Passion vine.
53. *Persea gratissima* (2)	Avocado.
54. *Phoenix dactylifera* (3)	Date palm.
55. *Psidium cattleyanum* (1)	Strawberry guava.
56. *Psidium guayava* (1)	Sweet red and white lemon guavas.
57. *Psidium guayava pomiferum* (1).	Common guava.
58. *Psidium guayava pyriferum* (3).	Waiawi.
59. *Prunus persica* (1)	Peach.
60. *Prunus persica* var. *nectarina* (1).	Nectarine.
61. *Prunus armeniaca* (1)	Apricot.
62. *Prunus* spp. (1)	Plum.
63. *Punica granatum* (3)	Pomegranate.
64. *Pyrus* spp. (1)	Apple.
65. *Pyrus* spp. (1)	Pear.
66. *Santalum freycinetianum* (3).	Sandalwood.
67. *Solanum melongena* (3)	Eggplant.
68. *Spondias dulcis* (3)	Wi.
69. *Terminalia chebula* (1)	Natal plum.
70. *Terminalia catappa* (1)	Tropical almond or winged kamani.
71. *Thevetia neriifolia* (1)	Bestill.
72. *Vitis labrusca* (3)	Grape.

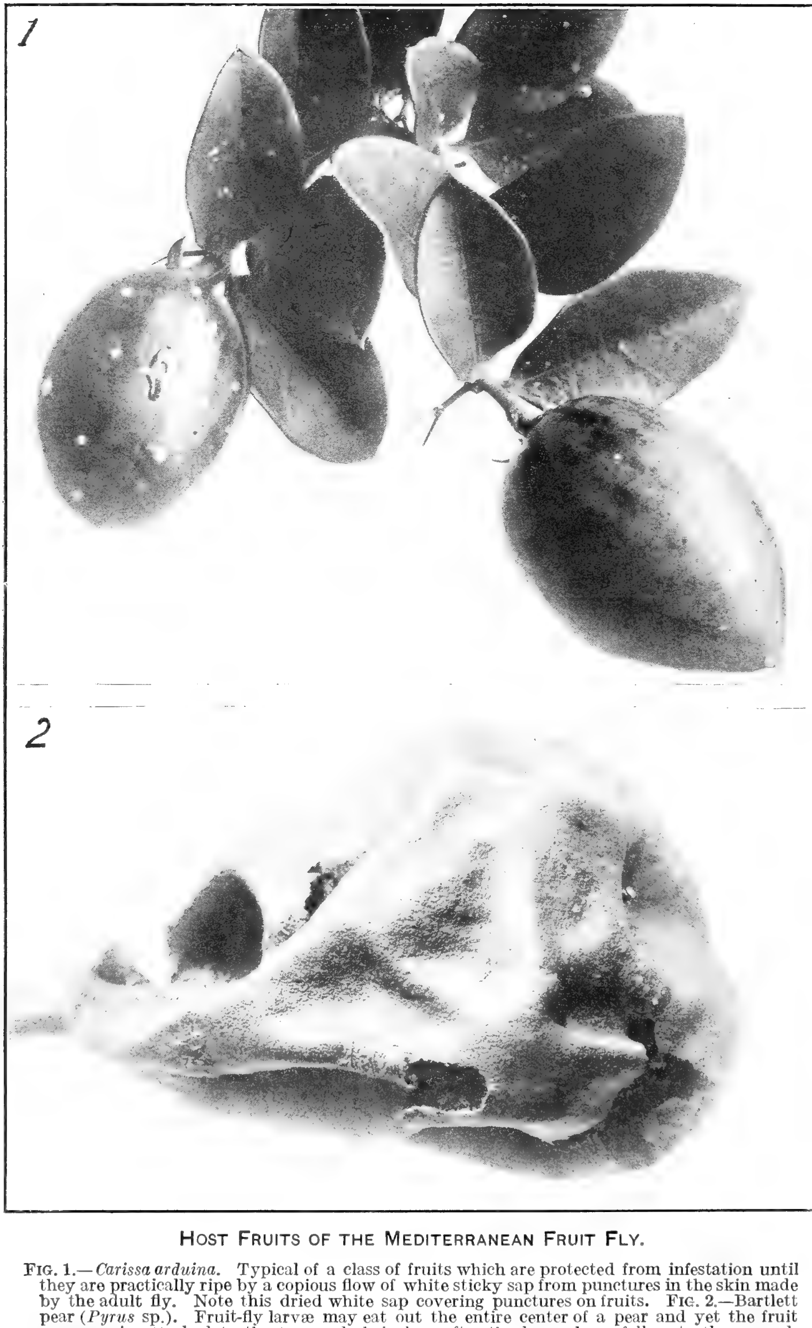
1. SAPODILLA (*Achras sapota*).

The sapodilla or naseberry (*Achras sapota*) is not a preferred host of *C. capitata* in Honolulu. A large percentage of the fruits ripen without becoming infested. Infestations are slight. Only 3 adults were reared from 1 fruit.



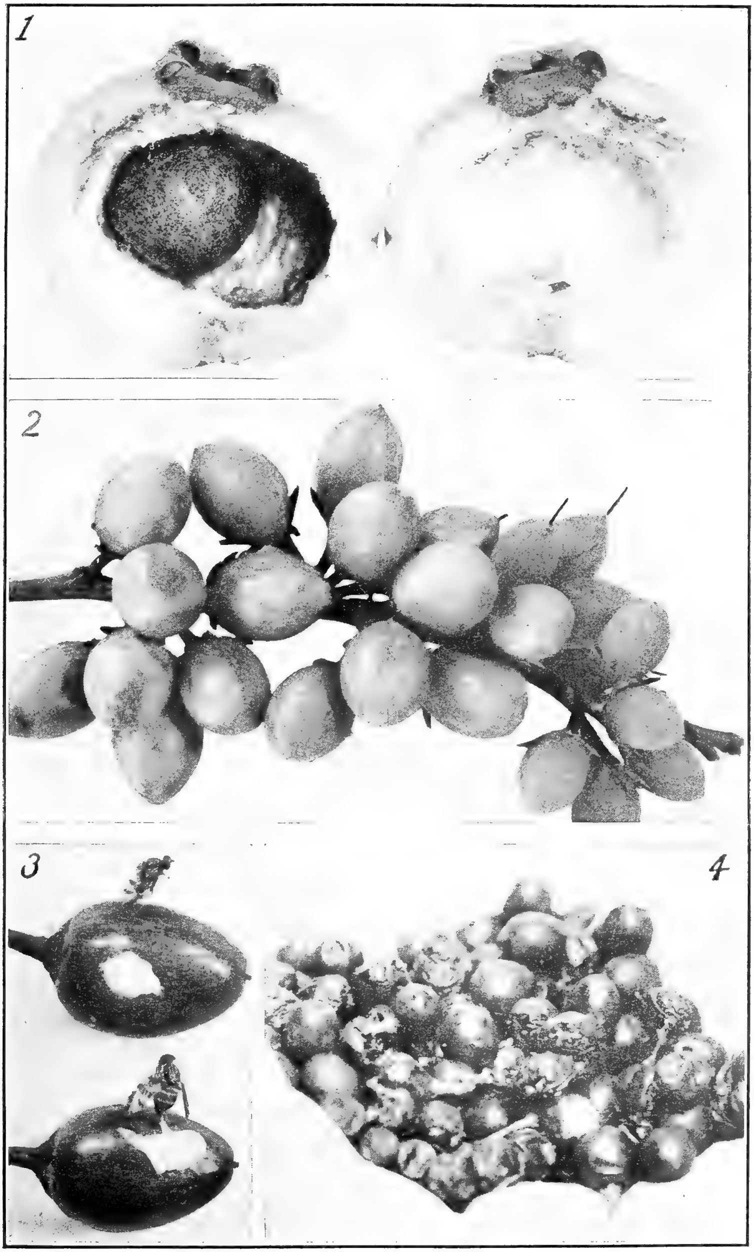
HOST FRUITS OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—A grove of large ball kamani trees (*Calophyllum inophyllum*) producing shade for a country home on windward Oahu. Fruits from these trees are badly infested and are falling throughout the year. FIG. 2.—The inedible fruit consists of a round seed, covered by a thin fibrous pulp in which the larvæ of the fruit fly work. (Original.)



HOST FRUITS OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—*Carissa arduina.* Typical of a class of fruits which are protected from infestation until they are practically ripe by a copious flow of white sticky sap from punctures in the skin made by the adult fly. Note this dried white sap covering punctures on fruits. FIG. 2.—Bartlett pear (*Pyrus* sp.). Fruit-fly larvæ may eat out the entire center of a pear and yet the fruit may remain attached to the tree and shrivel up after the larvæ have fallen to the ground. (Original.)



FOUR FAVORITE HOST FRUITS OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—Rose apple (*Eugenia jambos*) sectioned to show the large hollow interior on the surface of which larvæ prefer to feed. FIG. 2.—*Mimusops elengi;* fruit of an ornamental tree which sheds its infested fruit throughout a 3 to 4 month period. FIG. 3.—Adult *C. capitata* captured in sticky exudations of solidified sap about punctures in *Chrysophyllum oliviforme*. FIG. 4.—A handful of mock-orange (*Murraya exotica*) berries. The mock orange fruits several times each year and the berries falling become hidden in the grass. (Original.)

2. Acordia sp.

The fruit of an Acordia with white fleshy pulp was found infested in Bermuda during December, 1913, by the senior writer. The fruit of the Acordia in Honolulu, which is a different species and more woody, is not infested.

3. Sour Sop (*Anona muricata*).

The sour sop (*Anona muricata*) is a fruit which is not ordinarily infested until well grown and is found in the markets in season in perfect condition. Under certain conditions it may become heavily infested. Of 6 overripe fruits, 5 yielded 95, 67, 132, 87, and 2 adults.

4. Sugar Palm (*Arenga saccharifera*).

A single adult fly was reared from the fruit of the sugar palm (*Arenga saccharifera*) during May, 1912, by the Hawaiian Board of Agriculture and Forestry. From a lot of 14 fruits gathered March 17, 1914, only 3 yielded adults. From these 3 fruits, 1, 4, and 2 flies were reared.

5. Breadfruit (*Artocarpus incisa*).

There are no definite records of infestations of the breadfruit (*Artocarpus incisa*). No adults were reared from 100 very much overripe fruits taken from the ground during August, 1914, and placed over sand in jars. Three larvæ were found in one partially decayed fruit, but they were the only ones ever seen by the writers in breadfruit during a three-year period.

6. Carambola (*Averrhoa carambola*).

The carambola (*Averrhoa carambola*) becomes infested usually only as it ripens, in spite of the fact that it is fragrant and thin skinned. Many fruits escape infestation even in badly infested districts. Of 40 very ripe fruits collected during September, 10 yielded no adults. The other 30 yielded 172 adults, 5 fruits yielding 2, 6, 11, 15, and 20 adults. Only 22 of 62 ripe fruits gathered during August produced adults; from these a total of 289 adults were reared.

7. Ball Kamani (*Calophyllum inophyllum*).

The ball kamani (*Calophyllum inophyllum*) is badly infested at times (Pl. VI). The adults oviposit very abundantly in the thin, stringy pulp covering the huge seed, as the fruit ripens, but successful larval development often depends largely upon whether the fruit in falling lodges in a place where it remains moist. The fruits on separate trees differ in regard to infestation. On certain trees the pulp may be largely consumed and the larvæ well grown when the fruit falls. Generally speaking, the larvæ in ball kamani are apt to be underfed, their pupæ unusually small, and the adults so depauperized that they may be undeveloped sexually. In a few instances where fruits have fallen in grass on the windward island areas the larvæ have developed to normal size. As many as 120 larvæ have been reared in one fruit. In April, 1913, 7 fruits taken from the ground in Honolulu contained 39, 86, 0, 27, 6, 82, and 115 larvæ. From 104 fruits picked from a tree at Waikiki during April, 1913, 927 larvæ emerged. Of 20 fruits taken from a second tree 11 yielded no adults; the remaining 9 yielded 77 adults, 19 being the largest number from any one fruit. Of 20 fruits of a thick-skinned variety picked from the tree, only 1 yielded adults; a single adult was reared from this fruit. From 1,555 fruits collected during December, 1915, 4,213 larvæ were reared.

8. Peppers (*Capsicum annuum* var. *grossum*).

Peppers (*Capsicum annuum* var. *grossum*) grown in market gardens and generally known as "bell" or "green sweet" peppers, and used uncooked in salads, are frequently, although not generally, infested. Five pounds of peppers gathered August 1

at Waikiki, containing very green as well as overripe fruit, yielded no adults when placed over sand in jars. Of 221 ripe peppers gathered at the same place during November, 1915, 213 were not infested; the 8 infested fruits contained from 1 to 5 larvæ each, or a total of 19 larvæ. Thirty-five adults were reared during December, 1913, from 100 ripe peppers, while from 13 peppers collected on March 25, 1913, 14 adults were reared. The fruit fly was first reared from peppers in Honolulu by E. M. Ehrhorn, who reared 6 adults from peppers collected at Kaimuki. While there are reports that all peppers are infested, the writers have never known infestation to exceed 5 per cent of the fruits examined.

Chile peppers (*Capsicum* spp.) have never been found infested by the writers, although many fruits have been under observation.

9, 10. Papaya (*Carica papaya* and *C. quercifolia*).

The papaya (*Carica papaya*) is one of the commonest plants about Honolulu and its fruit is the universal breakfast fruit, yet the writers have never seen a fruit sufficiently ripe and fit for eating purposes infested with larvæ. Only fruits too ripe for the table or those having decayed spots are found infested. Sound fruits cut from the tree several days before they soften, a practice which is customary among fruit dealers, are always free from infestation. The milky juice which exudes copiously from cuts in the skin of the fruit contains a digestive principle said to be similar to pepsin. The hands of horticulturists working with the papaya soon become sore if exposed to this juice. It has been shown by Knab and Yothers that the larvæ of the papaya fruit fly (*Toxotrypana curvicauda*) can not live in the pulp of papayas still green, because of this juice. This is true also in the case of *C. capitata* until the fruits are ripe, although several of about 500 eggs introduced artificially into well-grown but still green-colored papayas attached to the tree were able to hatch; the larvæ died. It has been stated in Honolulu that fruits were infested while still green, but the writers have never been able to verify this and all evidence would appear to disprove it.

During January, 1914, an adult female was observed ovipositing in a perfectly sound fruit that was just beginning to turn color. Much juice had exuded around the ovipositor and had formed a gummy semisolid globule. After about 3 minutes the fly withdrew her ovipositor with comparative ease, but the mass of solidified juice remained fast to the tip of the abdomen. The fly freed herself from this mass with considerable difficulty. Seven eggs were found within the puncture, but they failed to develop.

During the winter months very ripe fruits are more heavily infested, as a rule, because of the relative scarcity of other hosts. From 2 fruits picked from the tree on January 18, 1914, 205 and 67 adults, respectively, were reared. Thirty-eight adults were reared from a decayed area in a fruit picked July, 1913. From 6 fruits gathered during May and June, 1913, 27, 13, 49, 2, 30, and 61 adults, respectively, were reared. From one lot of 7 overripe fruits gathered during May only 1 was infested.

The dwarf papaya (*Carica quercifolia*) serves also as a host fruit of *C. capitata*.

11. *Carissa arduina*.

The fruits of *Carissa arduina* are often found generally infested. Even at as late a period in development as that when the fruit has turned deep red, slight abrasions in the thin skin are followed by exudations of white sap which dries about the punctures, as illustrated in Plate VII, figure 1. Every fruit becoming fully ripe on one hedge was found, during February, to be well infested and as many as 30 adults were reared from single fruits.

12. Sapota (*Casimiroa edulis*).

The white sapota (*Casimiroa edulis*) is quite generally infested about the time it ripens. Practically every ripe fruit falling to the ground is variously infested. As many as 40 adults have been reared from a fruit 2 inches in diameter. While green the fruits are protected by white sap which exudes copiously from skin abrasions.

13. Chinese Inkberry (*Cestrum* sp.).

The Chinese inkberry (*Cestrum* sp.) is seldom infested, although the trees produce an abundance of fruit. Samples of several hundred fruits, each taken from the ground among badly infested coffee trees, have yielded no adults. In one instance 3 adults were reared from fruits collected by the Hawaiian Board of Agriculture in Manoa Valley in November, 1911.

14. Star Apple (*Chrysophyllum cainito*).

The star apple (*Chrysophyllum cainito*) is a preferred host and is always grossly infested. The writers have not observed a single mature fruit during the past three years that was uninfested. The milky, sticky juice exudes from abrasions in the skin until the fruit is overripe. Often, as is the case with other species of Chrysophyllum, this juice solidifies so rapidly that the female fruit fly is caught by the ovipositor and held captive until death. From four very ripe fruits collected at Haleiwa, May 30, 1913, 188, 110, 105, and 5 adults, respectively, were reared. Five fruits from the same tree, picked May 27, 1914, yielded 18, 96, 54, 105, and 44 adults, respectively.

15. Damson Plum (*Chrysophyllum oliviforme*).

The small plum *Chrysophyllum oliviforme* is one of the preferred hosts of *C. capitata*. Like its relative, the star apple (*Chrysophyllum cainito*), it is well protected by the white sticky juice which exudes rapidly from breaks made in its skin until quite well grown. (Pl. VIII, fig. 3.) Although larvæ develop to a very large size in this fruit and scarcely a fruit ripens uninfested, the average number of larvæ per fruit is small. Of a sample of 48 fruits collected during February, 18 produced no adult flies. From the remaining 30 fruits an average of 2.4 adults resulted, 14 being the largest number of adults reared from a single fruit.

16. *Chrysophyllum polynecium*.

This fruit, which is round and about half an inch in diameter, is congeneric with the star apple (*Chrysophyllum cainito*) and the Damson plum (*Chrysophyllum oliviforme*). Like them it is a preferred host and always grossly infested. From two lots of 500 fruits each gathered from the ground during May, 1914, 1,584 and 1,140 adult flies were reared.

17–26. Citrus Fruits.

In a previously published paper [1] on the susceptibility of citrus fruits, the writers present data secured under Hawaiian conditions which show why such thin-skinned fruits as the tangerine, mandarin, Chinese orange, and kumquats are readily infested, and why oranges, lemons, and grapefruit resist infestation of the pulp with such remarkable success. All varieties of citrus have been found in Hawaii containing well-grown larvæ of *C. capitata* in their pulp and first-instar larvæ transferred to the sourest, and even half-grown lemons have been reared to the adult stage, so there is no question as to the correctness of classifying all citrus fruits among the hosts of *C. capitata*. While it seems evident that the acidity of partially ripe lemons has a detrimental effect upon larval growth, it has been proved experimentally and by field observation, both by Quayle and the writers, that no fruit is too acid for larval development. Savastano, in 1914, giving the results of experimental work carried on in Italy, exaggerates the part played by the acidity of citrus fruits in protecting them from *C. capitata* attack. In Hawaii his conclusions have not been borne out by the results of investigations by the writers. The data in Table VIII are presented in detail because of the difference of opinion existing between investigators as to the cause of egg and larval mortality in the citrus groups. The conclusions of the writers, based upon extensive examinations,

[1] Back, E. A., and Pemberton, C. E., Susceptibility of citrus fruits to the attack of the Mediterranean fruit fly. Jour. Agr. Research, v. 3, no. 4, Jan. 15, 1915.

are that, in Hawaii at least, citrus fruits resist fruit-fly infestation of their pulp in proportion to the thickness and texture of the rag underlying the rind, the quantity of oil liberated from the oil cells during the process of oviposition, and their ability to develop quickly about the egg cavity the gall-like tissues which so often make of the cavity a prison for the larvæ that hatch. The data in Table VIII emphasize the large numbers of eggs deposited in the skin of *Citrus* spp., and the relatively small number of these that produce larvæ able to reach and enter the pulp except in the Chinese oranges, limes, and tangerines. Larvæ that succeed in entering the rag from the egg cavity in the rind are unable to reach the pulp except in astonishingly small numbers because of the imperviousness of the rag. It is the persistent attack of successive lots of larvæ hatching from different batches of eggs, laid very often in the same puncture, that finally breaks down the barrier between the young larvæ and the pulp. If the types of mortality among eggs and larvæ in the rind of oranges, grapefruit, and lemons protect those fruits so well under Hawaiian conditions, where the weather is so warm that the adult flies can deposit their eggs every day in the year, they should constitute a valuable factor in control when supplemented by climatic cultural conditions more adverse to the development of *C. capitata* in other countries.

TABLE VIII.—*Infestation of citrus by the Mediterranean fruit fly.*

Fruit.	Punctures.		Eggs, appearance.		Larvæ.					
					Alive.			Dead.		
	Empty.	Not empty.	Normal.	Abnormal.	In puncture.	In rag.	In pulp.	In puncture.	In rag.	In pulp.
Chinese orange:										
1	0	2	15				6			
2	0	1					4			
3	0	1					8			
4	0	2	9				5	4		4
5	0	1					9			
6	0	1		26						
7	0	1					7			
8	1	1					19			
9	0	1					3			
10	0	1						1		6
11	0	1							6	
12	0	4	15				12			
13	0	3		12			7			
14	0	1					11			
15	0	1					5			
Lime:										
1	10	0							13	
2	6	5	15							
3	7	4	34					4	4	
4	4	6						10	30	
5	1	5	53	1			1	21	1	
6	6	9		1				20	15	
7	0	7	33				9	33		
8	3	5	80	2				9	11	
9	3	0								
10	8	9		15				56	4	
11	0	9							49	
12	6	5	61	27				6	3	
13	4	2						7		
14	9	2		15				2		
15	7	7		44				9	17	
16	5	0								
17	11	0								
18	5	13		14				14	37	
19	7	9						30	12	
20	5	0								
Grapefruit:										
1	7	25	83	514				19	28	
2	1	12	369	111		1		26	4	
3	0	3	17	16	1			10		
4	2	3	4						5	
5	5	6	42	9				4		
6	7	14	43	203				13	45	

TABLE VIII.—*Infestation of citrus by the Mediterranean fruit fly*—Continued.

Fruit.	Punctures.		Eggs, appearance.		Larvæ.					
					Alive.			Dead.		
	Empty.	Not empty.	Normal.	Abnormal.	In puncture.	In rag.	In pulp.	In puncture.	In rag.	In pulp.
Grapefruit—Contd.										
7	8	14		484				17	7	
8	4	19	9	666				10	7	
9	2	4		69				59	61	
10	5	24		404					89	
11	1	11		232				5		
12	14	8	32	75	8			25		
13	0	27	5	385				3		
14	0	18	88	208				4	9	
15	0	5		86	3					
16	0	11	8	195				19	15	
17	0	6		42	8			6		
18	0	4		74						
19	0	10		307						
20	0	13		329				29		
Lemon:										
1	3	4	23		[1] 29			4		
2	0	2	30					13		
3	5	0								
4	4	1		7						
5	14	4	15					18		
6	2	2	3					9		
7	3	2	5					4		
8	4	0								
9	28	12	47	60				14		
10	8	3	15	12						
11	6	10	129	32				2		
12	11	5	39	15				1		
13	9	5	38	2						
14	15	1	10					1		
15	4	0								
16	16		64						5	
17	8	2	10							
18	1	0								
19	7	0								
20	12	15	19	53				82		
21	30	3	11							
22	53	10	23	21				9		
23	12	3		18				20		
24	11	5		45				12		
25	5	2		3				3		
26	5	0								
27	2	4	14	1				4	10	
28	6	22	0	71				32		
29	2	1	44							
30	4	8	62	20				12		
31	4	1	0	7						
32	11									
33	6	12	67	122				16		
34	4	2						7		
35	4	2	16					5		
Sweet orange: [2]										
1	2	7						41	10	
2	13	11						42	29	
3	0	2							25	
4	2	5						15	5	
5	2	3						14	3	
6	0	1							6	
7	0	12						17	45	
8	5	16						83	6	
9	1	1		4						
10	2	8						37	27	
11	0	2						11		
12	2	5						19	26	
13	1	4						36	12	
14	1	5					[3] 5	13	19	
15	1	9	21					6	94	
16	7	17						75	58	

[1] These 29 newly hatched larvæ were feeble and appeared to be about ready to die.
[2] Fruits of sweet oranges 1 to 13 picked Mar. 7, examined Mar. 10, 1914; 14 to 20 picked Feb. 24, examined Mar. 6 and 7, 1914; 21 to 26 picked Sept. 10, examined Sept. 16, 1913; 27 to 29 picked Sept. 10, examined Sept. 18, 1913; 30 picked Sept. 4, examined Sept. 15, 1913.
[3] Third-instar larvæ in pulp; orange not decayed.

TABLE VIII.—*Infestation of citrus by the Mediterranean fruit fly*—Continued.

Fruit.	Punctures.		Eggs, appearance.		Larvæ.					
					Alive.			Dead.		
	Empty.	Not empty.	Normal.	Abnormal.	In puncture.	In rag.	In pulp.	In puncture.	In rag.	In pulp.
Sweet orange—Con.										
17	0	8						0	45	
18	2	11							79	
19	6	4						3	25	
20	5	5		9			[1] 12	19	10	
21	7	20	3	25				107	63	
22	15	18	7	24				66	51	
23	8	9		33				7	29	
24	29	16	12	68				18	37	
25	4	13	14	21				48	65	
26	3	10		21				35	13	
27	4	9	40	30				27	6	
28	10	12	25	52					37	
29			13	17				52	40	
30	12	11	150	36						
Sour orange:[2]										
1	5	5	11	15		9			1	
2	2	6	0	94				31		
3	3	8	19	15				6		
4	2	8	30	32			11			
5	0	8	12	10				37		
6	3	10	75	250				32	14	
7	2	8	4	45				24	7	
8	1	7	7	57			59	16		
9	1	7	0	4	18		7	23	10	
10	4	9	10	48				43		
11	1	27	12	48			28	51		
12	1	12	36	116				36		
13	1	5	0	25				16	7	
14	2	2	10	14			25			1
15	0	2	0	9			36			
16 [3]							49			
17	7	0								
18	2	1	5							
19	4	4	57	12						
20	1	2	0	44	2					

[1] Third-instar larvæ in pulp beneath soft but undecayed spot in rind.
[2] Fruit of sour oranges, 1 to 16 picked Mar. 3, examined Mar. 10 and 11, 1914; 17 to 20 picked Sept. 4, examined Sept. 5, 1913.
[3] Very badly decayed.

17–21. CITRUS FRUITS EASILY INFESTED IN HAWAII.

The varieties of *Citrus japonica* in Hawaii known as the Chinese orange and the kumquats ("testa di turco" of the Italians), of *Citrus nobilis*, known as the mandarin and tangerine, and of *Citrus medica limetta*, or lime, are easily infested by *C. capitata*. The data of Table VIII on the infestation of Chinese oranges and Hawaiian limes are introduced as examples of infestation for the varieties of *C. japonica* and *C. nobilis*. The rind of the Chinese orange and of many limes, mandarins and tangerines is so thin that the adult fly is able to deposit eggs either directly within the pulp or between the rind and the skin covering the pulp, but parallel with the rind and at a slight distance away from the ruptured oil cells where they more often escape the fatal action of the oil or hindrances in the form of a dense rag. Of 609 eggs deposited between the rind and the pulp in Chinese oranges, 98.5 per cent hatched and the larvæ, unhindered by the presence of an impervious rag, entered the pulp. The infestation of the pulp of limes, tangerines and mandarins is in inverse proportion to the thickness of the rind. It is interesting to note that eggs in the Kusaie limes, the rind of which is sufficiently thick so that the eggs are usually deposited directly beneath the puncture, die with great regularity, while the eggs in Hawaiian limes, the rind of which may be sufficiently thin to permit the eggs being deposited as in Chinese oranges, or so thick (according to

the individual tree) that the eggs are laid either in the cavity in the rind, or between the rind and pulp but directly beneath the puncture, suffer a degree of mortality between that of eggs deposited in Chinese oranges and Kusaie limes. Mandarins and tangerines in Hawaii usually are infested if allowed to ripen thoroughly upon the tree. The Satsuma orange is a fruit that easily becomes infested because of the looseness of the rind and lack of well-developed rag.

22. Lemon.

Because of the danger of introducing the Mediterranean fruit fly from the Mediterranean regions in lemons, the importance of this fruit as a host has been thoroughly investigated at the request of Mr. C. L. Marlatt, chairman of the Federal Horticultural Board. The observations of Martelli and Savastano in Italy have led them to definite statements as to the immunity of commercial lemons to *C. capitata* in Italy. H. J. Quayle, who conducted an investigation during 1913 in the Mediterranean citrus regions under the direction of the Federal Horticultural Board, found less than 15 lemons with infested pulp during a search of eight weeks throughout commercial lemon orchards in Italy and Sicily. It is interesting to record that of the 15 fruits containing larvæ within the pulp, all had the appearance of having been injured, either mechanically or by fungi, and in all but two instances they were found in an overripe and overdeveloped condition on the ground beneath the trees. The two fruits found infested while still attached to the tree were partly decayed on one side. These instances of infestation recorded by Quayle, who is thoroughly competent to judge from long experience with citrus in California, refute the argument that lemons are too acid to support *C. capitata* larvæ, although the small number of lemons found infested, of the thousands examined during the eight-week period, strengthens the argument set forth by the Italian entomologists, as well as by the writers, that lemons, commercially grown and cured, will not support the fruit fly if they are not first subjected to some mechanical or other injury while still attached to the tree.

In Hawaii, where climatic and host conditions are so favorable to *C. capitata* activity and where every host is subjected to the severest tests, the writers have never found a lemon of either the commercial or the rough-skinned type showing infestation of the pulp unless it had first received mechanical injuries. Although there are comparatively few lemon trees in Hawaii, those known to the writers have seldom been found infested. By "infested" is meant, in this instance, an infestation by *C. capitata* larvæ in the pulp. Out of 235 well-grown and for the most part ripe lemons of the commercial type, picked from the tree, only one eventually developed adults, three in number, and this fruit when picked was partially decayed as the result of a thorn prick. Out of 161 lemons of the same variety taken from the ground in a very much overripe condition, only two developed larvæ, 1 and 5, respectively. No larvæ developed in 434 ripe, rough-skinned, but badly punctured lemons picked from the tree. One partially decayed rough-skinned lemon picked from the ground produced 12 larvæ. These instances of infestation of the pulp, taking place in the field, are the only ones which have come to the attention of the writers during the past four years in Hawaii.

The recording of so small a number of lemons with larvæ developing in their pulp should not be interpreted as meaning that lemons are particularly free from attack in Hawaii. The data of Table VIII prove that, in reality, lemons of the commercial type grown in Hawaii are very attractive to adult *C. capitata* as host fruit. The many fruits listed above from Hawaii from which no adults were reared were as heavily infested in the peel as those recorded in Table VIII. Particular attention is drawn to this point since it is the contention of the writers that the immunity of lemons, otherwise uninjured, is due not so much to the acidity of the pulp as it is to the imperviousness of the rag. It seems incredible that lemons heavily oviposited in should be able to resist successfully infestation of their pulp, yet this is true. Examination of 5 lemons showed that 73 of 79 egg cavities or punctures had been made between the

oil-cells, hence the immunity of lemons is due chiefly to the imperviousness of the rag and the gall-like developments about the egg cavity which make it difficult for the hatching larvæ to leave the cavity.

In the laboratory a comparison was made between the infestation of the rind of cured California lemons and well-grown fruits picked fresh, both green and yellow in color, from the trees. About the egg cavities in freshly picked fruits infested by adults in the laboratory, a hard, more or less gall-like condition of the walls and adjoining tissues develops rapidly. In the well-cured fruits no such gall-like hardenings were detected following infestation, and after hatching the larvæ had little difficulty in working their way out of the puncture into the rag. Thus six California-grown lemons such as are found on the markets were exposed between April 3 and 5, 1915, in large glass jars containing each about 200 flies. After removal they were held until April 12, when an examination showed them to have been oviposited in 16, 26, 31, 29, 39, and 20 places, respectively. Of the 161 punctures, only 8 had been made in, or through, an oil-cell and in these the *C. capitata* (numbering, respectively, 2, 1, 1, 3, 0, 2, 5, and 8) were dead. From the remaining 153 punctures, made between the oil-cells, 441 larvæ had escaped into the rag beneath, where, without exception, they were found dead. Other well-grown but greenish colored lemons were gathered from the trees and immediately exposed to adults within similar glass jars between April 14 and 16, 1915. These fruits were examined April 19–20. Before being exposed in the jars all punctures in the rind, made previously in the field, were covered with gummed paper. The results of the examination of two of these fruits are given here as typical:

Fruit No. 1.

Puncture 1. One dead larva in puncture located between oil-cells.
2. One unhatched egg in puncture in oil-cell.
33. Three unhatched eggs in puncture between oil-cells.
4. Six unhatched eggs in puncture between oil-cells.
5. Two larvæ barely alive in rag beneath puncture made between oil-cells.
6. Five unhatched eggs in puncture between oil-cells.
7. Seven unhatched eggs in puncture between oil-cells.
8. Four unhatched eggs in puncture between oil-cells.
9. Six dead larvæ in puncture between two oil-cells.
10. One dead larva in puncture between two oil-cells and one dead in rag close by.
11–19. These nine punctures were shallow and contained nothing.

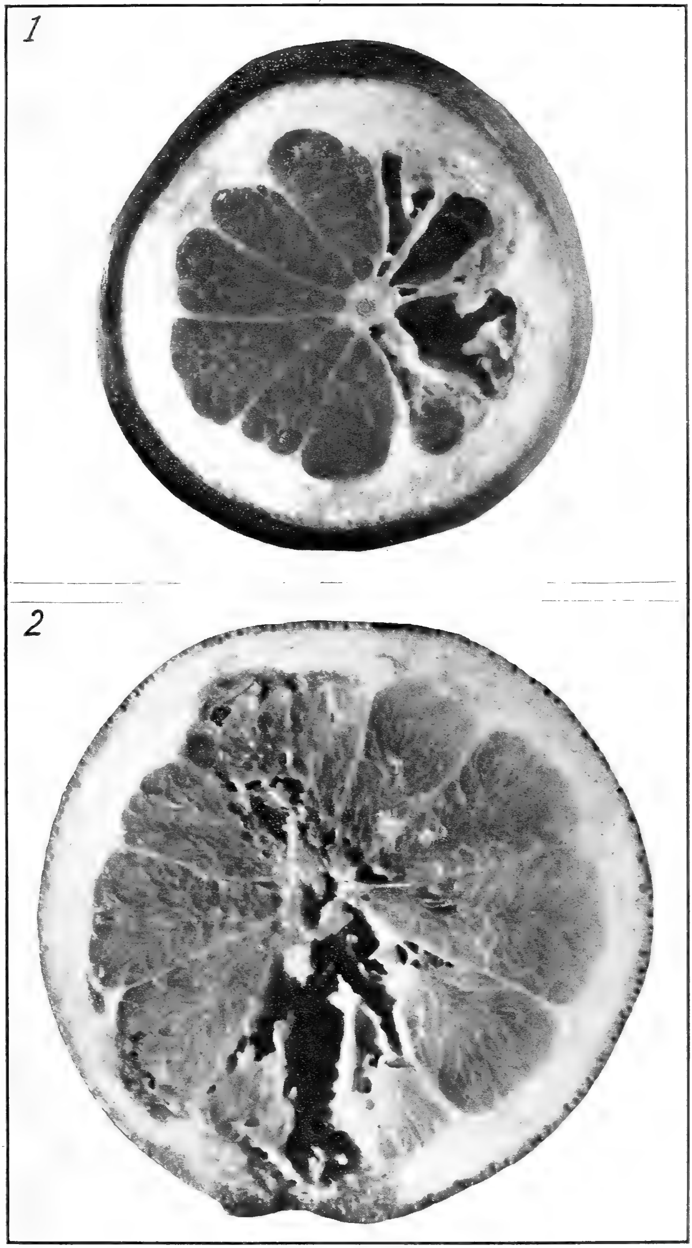
Fruit No. 2.

Puncture 1. Nine dead larvæ in rag beneath puncture between oil-cells.
2. One dead larva in puncture made between oil-cells.
3. Four dead larvæ in puncture made between oil-cells.
4. Three unhatched eggs in puncture made between oil-cells.
5. One dead first-instar larva in rag beneath puncture made between oil-cells.

These data indicate the way citrus fruits are protected from infestation of the pulp, and they supplement previously published data on the development of larvæ within lemons.

23. Grapefruit.

The ordinary types of grapefruit which have come under the observation of the writers have been particularly resistant to attack up to the time when they are fit for table use as indicated by the data of Table VIII. These data were secured during September. Many fruits from these trees in Manoa Valley, Honolulu, which were sufficiently ripe to fall to the ground, have been held over sand in the laboratory but yielded no adult flies. The writers have found other trees bearing fruits with rinds of a looser texture from which they have reared adults, and in certain instances have found fruits still attached to the trees, which, though much overripe, were badly infested. It seems very probable, therefore, that should the fly reach the citrus regions of the mainland, certain thin-skinned varieties of grapefruit might



GRAPEFRUIT AS A HOST OF THE MEDITERRANEAN FRUIT FLY.

Two types of infestation. FIG. 1.—Larvæ have eaten out a portion of the fruit while the rest remains unaffected. FIG. 2.—Infestation extending throughout the pulp. Note that the rind shows evidence of infestation of the pulp only at the decayed spot on the lower side. (Original.)

THE ORANGE AS A HOST FRUIT OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—Orange infested with larvæ of the Mediterranean fruit fly. Note that the fruit looks sound, except about the irregular hole, through which a few well-grown larvæ have already left the fruit. FIG. 2.—Orange infested with larvæ of the Mediterranean fruit fly showing two breathing holes of the larvæ in the decayed area. (Author's illustration.)

become seriously infested unless gathered and sold early. Three grapefruit out of five dropping from the tree in an overripe condition, two months after they had been marked as sufficiently ripe for eating, produced four, two, and four adults. It is interesting to record that when these five fruits were marked they already had been oviposited in. E. M. Ehrhorn reared 16 adults from an overripe grapefruit grown in the Punahou district of Honolulu during November, 1911. The grapefruit grown at ex-Gov. Frear's city and mountain residences have been found infested when much overripe. The fruits used as illustrations (Plate IX) were taken from Tantalus during a particularly wet season when it appeared to the writers that the action of numerous showers had aided the larvæ in breaking down the protective rag of the rind.

The exudation of gum from punctures does not always occur, although at times it may be very excessive in Hawaii.

24. Shaddock.

The large, very thick-rinded shaddocks are not infested successfully until they are very much overripe. During March, 1914, fruits were gathered from a tree in Hilo, Hawaii, from which fruits had been taken for the table during the months of January and February. During those months no infestation of the pulp had been noted by the owner. Examinations made of the fag end of the crop showed that larvæ had successfully penetrated the pulp and had been able to burrow about through the loose-textured rag. Instances were found in which the larvæ had completed their entire development within the rag. As many as 22, 17, 9, 17, 16, 25, 19, 8, 1, and 18 living larvæ were found in the rag of 10 fruits. Of these 10 fruits only four possessed 27, 13, 3, and 12 living larvæ in the pulp. On examination, made at the same time, of equally ripe fruits of another shaddock tree that possessed a firmer rag, there were found 6 normal and 39 abnormal appearing eggs; 5, 2, and 3 living larvæ in the punctures, rag, and pulp, respectively; and 405, 696, and 1 dead larvæ in the punctures, rag, and pulp, respectively.

25. Sweet Oranges.

Oranges are subject to severe attack from the time they are nearly grown until they fall to the ground or are picked. (See Pl. X.) Ten oranges just beginning to turn color, collected in Honolulu in November, 1915, had 14, 33, 74, 4, 22, 13, 99, 11, 20, and 14 punctures, respectively, in their rind; 10 others of another crop gathered during June, 1913, had 29, 17, 34, 14, 11, 17, 33, 17, 18, and 17 punctures, respectively. Ten ripe fruits picked in the same general locality as these 20 fruits during October, 1915, had 21, 2, 17, 10, 10, 3, 2, 46, 9, and 3 punctures, respectively. In spite of the fact that 39 oranges picked in September when they were just becoming well yellowed had an average of 32 punctures per fruit, none of them developed larvæ within the pulp. But of 784 oranges gathered during March, 1914, when very much overripe, 254 produced 2,272 larvæ, or an average of 9 larvæ to the fruit. Such data as these, coupled with the more detailed data of Table VIII, throw much light on the wonderfully resistant power of oranges to fruit-fly attack. Were oranges not so well equipped by nature to withstand attack they would be ruined long before any of them could ripen. Considering the number of eggs deposited, very few adults emerge even from fruits that become infested in the pulp. Thus, only 5, 13, 4, 1, 6, 12, 6, 30, 8, 4, 1, 1, 14, 26, 1, 12, 31, and 2 adults were reared from 18 fruits picked because they appeared to be badly infested.

26. Sour Oranges.

The ordinary sour orange commonly found in Florida groves is as severely attacked as is the sweet orange, but on account of the looseness of the rind and rag it becomes infested in the pulp more easily. A larger percentage of fruits become infested in the pulp when well ripened than of sweet oranges. (See Table VIII for data on infestation.)

27. Wampi (*Clausena wampi*).

The wampi (*Clausena wampi*) is a native of China. While a large percentage of the fruit produced by a tree growing at Beretania and Punahou Streets, Honolulu, was found free from attack during June, 1914, certain overripe fruits contained larvæ of *C. capitata*. From 200 fruits gathered during July, 1913, only four adults were reared.

28, 29. Coffee.

Coffee cherries (*Coffea arabica* and *C. liberica*) are favorite hosts of the Mediterranean fruit fly. *Coffea arabica* is grown in various portions of the Hawaiian Islands, but commercially, at the present time, only on the island of Hawaii. (Pl. V.) During the fiscal year ended June 30, 1915, there were exported from the islands 4,363,606 pounds of raw coffee beans valued at $651,907, besides the coffee locally consumed. Fortunately for the coffee growers in Brazil and Africa, as well as in Hawaii, the larvæ of the fruit fly attack only the pulp of the cherry surrounding the beans or seeds and in no way affect the value of the latter. The chemical analyses of Miss A. R. Thompson, formerly of the United States experiment station at Honolulu, have proved that beans from infested cherries do not differ chemically from those from uninfested cherries, and tasting tests of coffee made from roasted beans by Messrs. L. Macfarlane and Robert Wallace, coffee growers of Hawaii, Mr. H. L. Lang, of the office of Home Economics of the United States Department of Agriculture, Dr. E. V. Wilcox, formerly director of the Hawaii Federal Experiment Station, and the writers have failed to discover differences in either the flavor or the aroma.

The unrestricted development of larvæ within coffee cherries does, however, bring about certain losses to the growers and mill owners that are apt to be overlooked except by those best informed. Before the introduction of parasites into the coffee districts cherries were infested, often as soon as they began to turn white from green, in the final ripening process. The larvæ, numbering from 2 to 8, were able to become nearly full grown by the time the cherries had turned red. An examination of the coffee cherries as illustrated (Pl. V, fig. 4) shows that the beans occupy the larger portion of the fruit. The pulp itself, with its thin, easily punctured epidermis, varies in thickness from 0.04 to 0.14 inch, or is scarcely thicker than a well-grown larva of the fruit fly. Therefore, by the time the cherry would ordinarily be ready for harvesting the larvæ have devoured practically all the pulp, leaving the seeds hanging more or less loosely within a sack composed of the thin epidermis. If the weather happens to be dry, the epidermis shrivels and hardens about the beans and the cherry remains on the branch indefinitely, resembling closely those killed by disease. However, should the harvesting season be rainy, the epidermis decays rapidly and under the weight of the beans the cherry falls to the ground. The writers have been in certain coffee fields where a slight jar to the tree would cause many cherries to fall to the ground, where they are lost. This type of loss necessitates extra pickings and greater cost of labor. Since the successful introduction of parasites the fruit fly has been so reduced, as discussed on page 99, that while cherries are infested in about the same proportion as formerly, the infestation occurs so late in the ripening process that extra pickings now are not necessary and the cherries on reaching the mills during the height of the harvesting season contain chiefly eggs or young larvæ which have not had an opportunity to reduce the pulp. Whether these improved conditions of 1914 and 1915 will continue remains to be seen.

For some time after the advent of the fruit fly into the coffee districts, prices for coffee in the cherry delivered at the pulping mills remained the same per pound. During 1912 and 1913 when the fly attack was severe it was difficult to find at the mills cherries which were normally bright red and sound. Practically every cherry that was red was badly infested and its pulp had been consumed, and the floors about the delivery platforms were well strewn with emerging larvæ. As the pulp only had been destroyed, a pound of coffee cherries badly infested contained in reality many

more coffee beans, or of that portion of the cherry that had any commercial value. Counts made of samples of badly infested cherries, and of those in which the infestation had not progressed sufficiently far to affect the weight, were made and the loss both in numbers and percentage of cherries is given in Table IX.

TABLE IX.—*Loss of weight and pulping quality of coffee cherries due to infestation by Mediterranean fruit fly.*[1]

Weight of sample.	Number of cherries.		Loss due to infestation.		Cherries failing to pulp.		Cherries partly pulped.	
	Badly infested.	Firm bright red.	In number of cherries.	In percentage.	Badly infested.	Firm bright red.	Badly infested.	Firm bright red.
6 pounds	3,060	1,980	1,080	54.5	692	0	334	25
10 pounds	3,675	2,892	783	27.1	833	11	699	227
4 pounds	1,828	1,277	551	43.1	274	3	357	274
3 pounds	1,171	736	435	59.1				
10 pounds	3,562	2,561	1,001	39.8				

[1] Attention is called to the fact that differences in the size and succulency of coffee cherries is responsible for the differences in the number of cherries per pound in the different samples. While several ordinary weighing machines were used in securing data in Tables IX and X, the uninfested and infested cherries or beans of the same sample were weighed on the same machine.

It will be noted that loss in the number of coffee cherries due to heavy infestation, when the cherry is sold by the pound at prices paid before the advent of the fly, ranged in the particular examples taken from 27.1 to 59.1 per cent. In practice, however, this loss is considerably reduced by the addition of half-ripe fruits in the fields. This loss has been appreciated by the small Japanese coffee growers and has been responsible, in the opinion of the writers, for the erection of many small pulping mills throughout the Kona coffee district. It has also encouraged coffee renters who deliver their crop at the large mills to put in their sacks a high percentage of "too-green" cherries which will not pulp and are therefore lost.

Badly infested cherries do not pulp as easily as do sound fruits, as shown in the data of Table IX. Thus in 6, 10, and 4 pounds of badly infested cherries, run through a gasoline pulping mill, 692, 833, and 274 failed to pulp, whereas in three samples of the same weight of unaffected cherries, 0, 11, and 3 cherries failed to pulp. The number of badly infested cherries that only partly pulped is also much larger than that of unaffected cherries.

To determine whether the beans from infested and noninfested cherries differed in weight after they had been dried and sacked for several months the beans of 1,000 cherries were weighed separately with the results given in Table X.

TABLE X.—*Relative weights of thoroughly dried beans from badly infested and uninfested coffee cherries.*

Weight of sample of dried beans from 1,000 cherries.					
Lot.	Infested.	Not infested.	Lot.	Infested.	Not infested.
	Ounces.	*Ounces.*		*Ounces.*	*Ounces.*
1	11	11	3	10	10
	11	11.5		10.5	10.5
	10.5	11	4	12	12
2	9.5	10		11.5	11
	10	10		11	11.5
	9.5	10		12	12
	9.5	9.5		12	12
	9.5	9.5			

The data indicate that the weight of the bean is not affected by infestation.

In experimental work coffee cherries should be avoided, if possible, as a source of fruit-fly larvæ unless one is working close to coffee fields. While from 2 to 8 larvæ may mature in each fruit if the fruit remains attached to the tree, the fruit heats and decays so rapidly after being picked and placed in containers that only a relatively small number of adults can be reared. Only 427 adults were reared from 1,500 ripe infested cherries placed over sand in lots of 25. If these cherries had been allowed to remain on the tree they would have produced at least 6,000 adults.

30. Quince (*Cydonia vulgaris*).

The quince (*Cydonia vulgaris*) is not grown in Hawaii, but fruits obtained from the mainland were readily infested. The quince is frequently infested in Australia, South Africa, and Spain.

31. Persimmon (*Diospyros decandra*).

The brown persimmon (*Diospyros decandra*) is the only Diospyros grown in Hawaii. Mr. G. P. Wilder has grown fruits a few of which have become infested on reaching maturity. From one ripe fruit 57 adults were reared during December, 1911, by the Hawaiian Board of Agriculture. The persimmon has been reported infested from Algeria, South Africa, and Australia.

32. Loquat (*Eriobotrya japonica*).

The loquat (*Eriobotrya japonica*) is badly infested in Hawaii, and appears to be a favored host. Infested loquats often hang on the tree and shrivel up after the larvæ have become full grown and dropped to the ground. When punctured before the fruits are ripe, the areas about the punctures remain green after the rest of the fruit turns yellow, thus making these infestations very evident. As many as 11 punctures have been counted in a single fruit. From lots of 200 and 150 fruits each, 1,261 and 990 adults, respectively, were reared. From one cluster of 17 fruits 458 adults, or an average of about 27 flies per fruit, were reared.

In Bermuda the loquats are badly infested and serve as a host by means of which large numbers of flies pass the winter and spring months.

33. Brazilian Plum or Spanish Cherry (*Eugenia brasiliensis*).

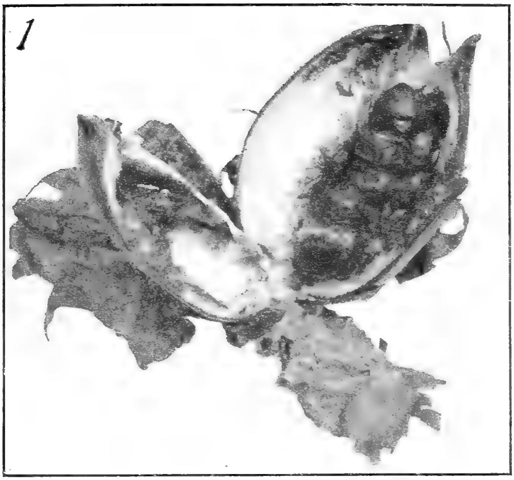
The Brazilian plum or Spanish cherry (*Eugenia brasiliensis*) is easily and badly infested. It is doubtful if a single fruit comes to maturity in Honolulu without becoming at least partially infested. The larvæ develop well in this fruit and often as many as 20 adults may be reared from a single fruit slightly over one-half inch in diameter.

34. Rose Apple (*Eugenia jambos*).

The rose apple (*Eugenia jambos*) (Pl. IV, fig. 2, and Pl. VIII, fig. 1) is a preferred host and is everywhere generally and badly infested about Honolulu. From 36 fruits gathered during July, 1913, in Manoa Valley there emerged a total of 1,688 adults, or an average of about 47 per fruit. Each fruit yielded adults, 10 fruits yielding 53, 6, 91, 36, 44, 58, 1, 18, 56, and 92, respectively. A total of 1,395 adults, or an average of 19.6, were reared from 75 fruits collected in Nuuanu Valley during March, 1914. One fruit from Kalihi Valley in July, 1913, yielded 20 adults.

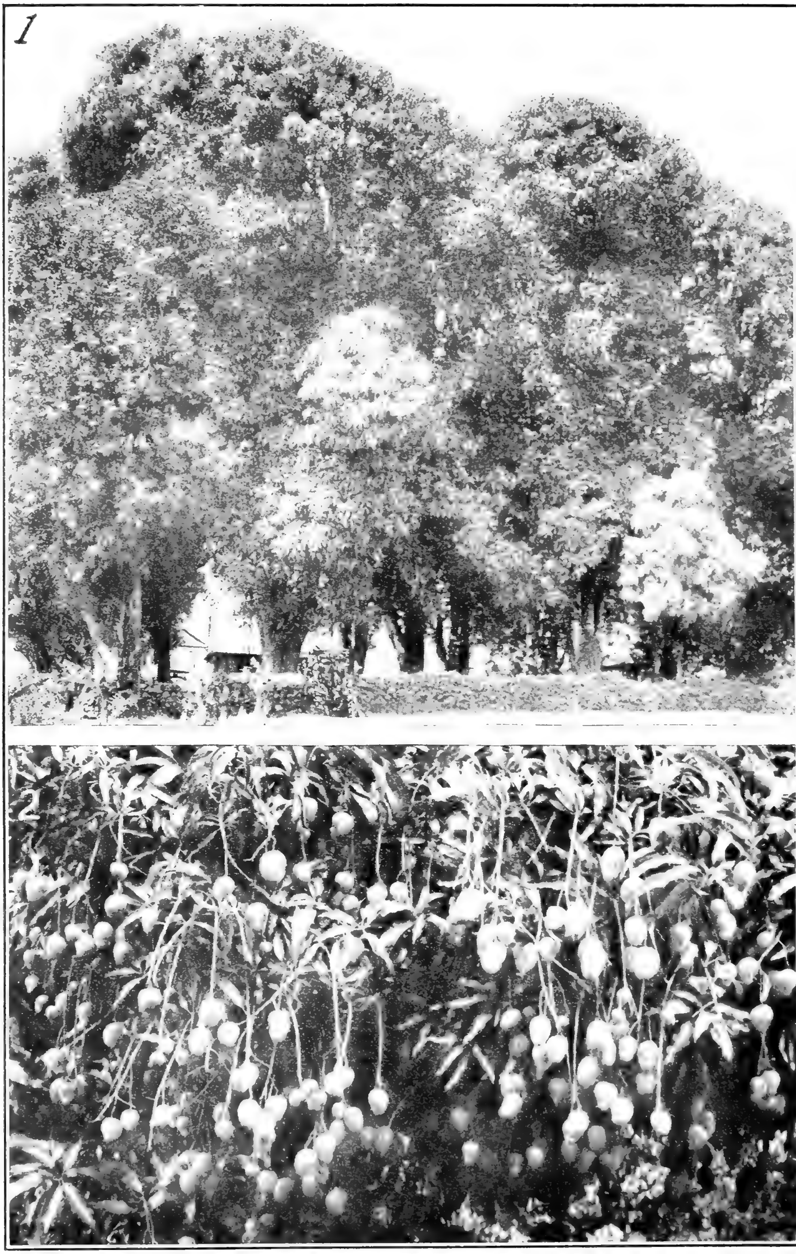
35, 36. Surinam Cherry (*Eugenia michelii*) and French Cherry (*Eugenia uniflora*).

The Surinam cherry (*Eugenia michelii*) and the French cherry (*Eugenia uniflora*), known in Spanish countries by the general term "pitangas," are fruits very generally infested, and although they never yield many adult flies in proportion to their size, very few fruits escape attack. In Bermuda the former was found to be one of the principal hosts of *C. capitata*. From 437 supposedly badly infested fruits gathered



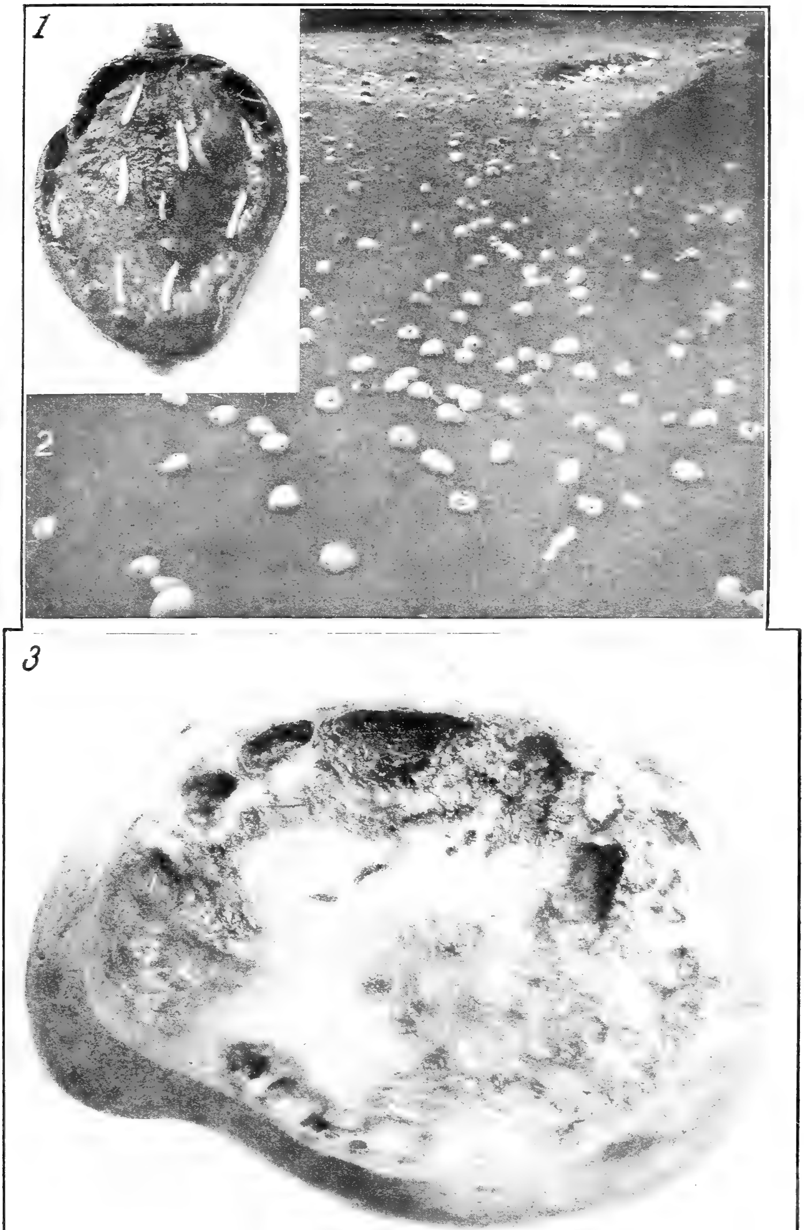
HOSTS OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—The Mediterranean fruit fly attacks cotton bolls about the time they are nearly full grown. This attack, however, appears to be of a secondary nature and follows that of the pink bollworm (*Pectinophora gossipiella*). As many as 10 well-grown larvæ have been removed from a single boll. FIG. 2.—Cross section of an apple (*Pyrus malus*) showing the destruction caused by feeding larvæ of the Mediterranean fruit fly. (Original.)



THE MANGO AS A HOST FRUIT OF THE MEDITERRANEAN FRUIT FLY.

Mango trees may become very large (fig. 1) and bear enormous crops of fruit (fig. 2), which, when ripening and falling, present impossible conditions for the fruit-fly inspector. (Original.)



THE MANGO AS A HOST FRUIT OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—Larvæ of the Mediterranean fruit fly, about natural size, in infested mango. FIG. 2.—No matter how diligently clean-culture inspectors gather fruit during the mango season, each day finds the ground beneath the trees well strewn with fallen infested fruits. FIG. 3.—Infested fruit about natural size. Note large cavity in upper right side containing several hundred white eggs. (Fig. 1, from Severin; figs. 2 and 3, original.)

during July, 1913, only 191 adults were reared. Of 45 fruits gathered during February, 1916, only 29 were infested. These 29 fruits yielded 55 adults, or an average of about 2 per fruit. Seven is the largest number of adults reared from any one of 16 infested fruits during April, 1913.

37. Fig (*Ficus carica*).

The fig (*Ficus carica*) is very generally infested. Because of the white, sticky sap which exudes copiously from abrasions made in its skin it does not become infested until the fruits are sufficiently ripe for the market. The larvæ are very small, as a rule, when the fruits are offered for sale and because of the interior structure of the fruit are easily overlooked. Only 6 out of 24 very ripe figs purchased in the market during July produced a total of 9 adult flies. Of ripe fruits purchased during March, 6 out of 22 produced 34 adults. From 12 apparently perfect figs, purchased during June, 36 adults were reared. Of 44 figs sufficiently ripe that little sap ran when they were gathered from trees in Manoa Valley, 10 proved to be uninfested. From the remaining 34 fruits 430 adults were reared, 12, 25, 28, 32, 44, and 48 adults being reared from 5 individual fruits. Kirk records rearing 241 adults from 7 figs imported into New Zealand from Australia.

38, 39. Mangosteens (*Garcinia mangostana* and *Garcinia xanthochymus*).

The mangosteens (*Garcinia mangostana* and *G. xanthochymus*) do not become infested until ripe. They are not preferred hosts under Hawaiian conditions. The writers have never reared more than an average of 2 adults from infested fruits. A large percentage of the fruits are uninfested.

40. Cotton (*Gossypium* spp.).

The Mediterranean fruit fly was first reared from cotton bolls (Pl. XI, fig. 1) on October 19, 1911, by E. M. Ehrhorn from bolls collected by D. B. Kuhns from trees growing on King Street, Honolulu. Numerous flies were reared during June, 1915, by August Busck from bolls collected on the U. S. Experiment Station grounds in Honolulu and at Kaneohe, Oahu. During the same month the writers found 10 out of 201 and 6 out of 174 bolls infested. In 10 bolls 32 larvæ were found, 10 larvæ being in one boll. In all cases infestation by *C. capitata* was secondary to attack by the pink bollworm, *Pectinophora gossypiella* (Saunders), and the larvæ of the fruit fly appeared to be feeding only upon the affected portions of the bolls rather than upon the cotton fiber itself.

41. Mountain Apple (*Jambosa malaccensis*).

The mountain apple, or "ohia ai" of the Hawaiians (*Jambosa malaccensis*), is a wild tree thriving well up to 1,800 feet elevation. The trees frequently are found growing in forests (Pl. IV, fig. 1). The fruits maturing in the forests do not appear to be more than slightly, and often not at all, infested. Fruits ripening on trees within the city of Honolulu are often badly infested. All the fruits ripening during August, 1914, on a tree growing in Pauoa Valley were infested. Ehrhorn reared adult flies from fruits from Kalihi Valley during August, 1911. As a rule, the fruits from the mountains, offered for sale in Honolulu, are free from infestation.

While none of three varieties of water apples (*Jambosa* spp.), of which there are a few trees in Honolulu, have been found infested, there is no reason why they should not be infested, as they are similar in texture to *Jambosa malaccensis*.

42. Blue Palm (*Latania löddigesii*).

One nut of 12 collected from a tree growing on Keeamaku Street, Honolulu, was found infested. Two adult flies were reared. Prof. O. H. Swezey has also reared adults from the overripe nuts of this palm.

43. TOMATO (*Lycopersicum esculentum*).

The ordinary cultivated tomato (*Lycopersicum esculentum*) is not generally infested by *C. capitata*, although many adults of *Bactrocera cucurbitae* and certain decay flies (Drosophilidae) are reared. Thus 270 ripe fruits gathered promiscuously from the market gardens of Waikiki during June, 1916, yielded no adult flies when held over sand in jars. Sixteen ripe fruits gathered from the market gardens of Moiliili on March 25, 1913, yielded the melon fly (*B. curcubitae*). It is interesting to note that of seven lots of tomatoes collected during 1911 and early 1912 by the Hawaiian Board of Agriculture, none produced adults of *C. capitata*. That *C. capitata* may be reared in numbers from tomatoes under field conditions has been demonstrated by the ease with which adults oviposit in both ripe and green, although well-grown, fruits in the laboratory under forced conditions. Of 4 ripe tomatoes placed singly for 7 hours in jars containing about 200 adults, only one yielded 3 adults, although all 4 were oviposited in and contained on removal from the jars an average of 13 punctures. One fruit yielding no adults contained 42 punctures. From one green but well-grown fruit exposed in a jar for 7 hours with 200 adults, only 5 adults were reared. From six other ripe fruits similarly exposed in two lots of 3 each, there emerged only 16 adults; and only 5 adults developed in one lot of 3 fruits containing 29 punctures in the skin.

The currant tomato (*Solanum pimpinellifolium*), the grape tomato (*Solanum lycopersicum*), and the "popolo" tomato (*Solanum nodiflorum*) have never been found infested. Newman writes that *C. capitata* has often been reported infesting tomatoes and other Solanum species, but that he had never reared from them any fly in Western Australia but *Lonchaea splendida* Loew, the tomato fruit fly—a fly which does not occur in Hawaii.

44. LICHEE NUT (*Litchi chinensis*).

The lichee nut (*Litchi chinensis*) is not infested so long as the fruits remain perfect. The shell-like covering of the fruits often splits as the fruit reaches maturity, and in the pulp thus exposed the adult can, and has been known to, deposit eggs. Several split fruits were found infested during September, 1913. One depauperized adult was reared by the Hawaiian Board of Agriculture from a split fruit during July, 1912. It is possible for infestation to occur in fruits infested by the tortricid *Cryptophlebia illepida* Btl. Seven ripe fruits, freshly picked and sound in every way, were hung in jars of adult flies for a two-day period during June, 1915. An examination of them after their removal proved that the flies had not been able to puncture the shell.

45. MANGO (Plates XII, XIII).

The mango (*Mangifera indica*) is a favorite host of the fruit fly. In Hawaii the common seedling varieties are so badly attacked that many owners are willing to have the crops removed and destroyed before they ripen. Twelve fruits picked from the ground in upper Manoa Valley yielded 313 adults, 95 adults emerging from one fruit. Of a total of 47 fruits from the same locality taken from the ground on July 27, 25 yielded 423 adults. Sixteen of 33 fruits taken from the ground at the Hawaiian Church, Manoa Valley, yielded no adults, but 502 were reared from the remaining 17 fruits. Of fruits taken from the ground on the Cooper estate, Manoa Valley, 26 of 35 yielded 527 adults during August. These records are fair samples of the infestation of seedling sweet mangoes in the outlying districts of Honolulu, where there are many wild guavas bushes.

The mango is one of the fruits subject to attack which becomes infested only as it ripens. Up to that time it is quite well protected from attack by the copious exudations of distasteful sap which follow attempts at oviposition. Often where the combined attack of the mango weevil (*Cryptorhynchus mangiferae* Fab.) and fruit-fly adults is severe the fruits are well stained with the exuded sap. It has been the experience of the writers that very few adults can be reared from hard well-grown fruits picked from or beneath trees on which many fruits are ripening and falling to the ground,

even where they show many indications of attempted oviposition. Thus from a total of 292 such fruits representing 12 lots collected from the ground in Pauoa Valley, Moanalua Gardens, and Nuuanuu Valley, during July and August, only 6 adults were reared. The thicker the skin of the fruit the more difficulty does the adult have in ovipositing successfully.

TABLE XI.—*Varietal susceptibility of mangoes to the attack of the Mediterranean fruit fly under forced conditions.*[1]

Combination of varieties.	Number of— Punctures.	Number of— Eggs.
Common mango	48	327
Cambodiana	8	61
Brinda Bani	0	0
Oahu	3	42
Piri	0	0
Brinda Bani	0	0
Common mango	8	73
Wood chutney[2]	60	584
Samoan chutney[2]	12	138
Common mango	5	52
Cambodiana	9	86
Wooten chutney	10	115
Common mango	40	293
Cambodiana (hard)	0	0
Cambodiana	18	182
Common mango	15	111
Strawberry	8	91
Brinda Bani	0	0
Strawberry	15	206
Seedling No. 1928	3	32
Brinda Bani	0	0
Divine	0	0
Wooten chutney[3]	44	314
Brinda Bani	0	0
Piri	1	68
Jamshedi	0	0
Divine	0	0
Wooten chutney[3]	6	27
No. 1928[3]	4	28
Cambodiana[3]	8	93

Combination of varieties.	Number of— Punctures.	Number of— Eggs.
Strawberry	16	139
Wood chutney	11	129
Brinda Bani	0	0
Common mango	14	129
Oahu	23	249
Totofori	0	0
No. 1928	3	18
Samoan chutney	29	291
Brinda Bani	0	0
Common mango	20	223
Wooten chutney	25	403
Totofori	7	43
No. 1928	0	0
Piri	0	0
Wood chutney	8	112
Piri (hard)	2	11
Piri (slightly soft)	21	196
Divine	0	0
Strawberry	1	5
Jamshedi	0	0
Strawberry[3]	14	132
No. 1928	4	42
Brinda Bani	0	0
Common mango[3]	4	35
Oahu[3]	5	38
Totofori[3]	7	40
Common mango	5	60
Wooten chutney	24	272
Totofori	0	0

Combination of varieties.	Number of— Punctures.	Number of— Eggs.
Common mango[4]	0	0
Jamshedi[4]	0	0
Divine[4]	0	0
No. 1928	1	9
Alphonse	0	0
Brinda Bani	0	0
Common mango	28	370
Oahu	5	59
Brinda Bani	0	0
Common mango	13	139
Strawberry[5]	25	178
Brinda Bani	0	0
Wooten chutney[4]	0	0
Wooten chutney[3]	5	38
Common mango	23	441
Cambodiana	0	0
Brinda Bani	0	0
Common mango[4]	6	53
Jamshedi[4]	0	0
Strawberry[3]	45	481
Common mango[3]	29	196
Piri[3]	2	14
Piri (hard)	0	0
Common mango[4]	1	11
Cambodiana[4]	0	0
Wooten chutney[3]	19	101
Wooten chutney	6	41
Divine	0	0
Brinda Bani	0	0

[1] Unless otherwise noted, the fruits used in each experiment were equally hard, though fully matured and from trees on which fruits had already begun to ripen.
[2] Less hard than the common mango.
[3] Soft.
[4] Very hard.
[5] Slightly softer than other two fruits.

While the common thin-skinned sweet mangoes are badly infested when they ripen, many chutney mangoes and certain highly developed horticultural varieties of eating mangoes are less susceptible to attack, owing, in the one instance, apparently to a greater amount of "turpentine" in the skin, and, in the other, to a much thicker skin. Under forced conditions adults will oviposit heavily in chutney mangoes which, ripening on the tree, escape infestation. Three fruits of a "Chinese" chutney variety[1]

[1] For purpose of future identification it may be stated that one tree of this variety is grown by Mr. G. P. Wilder, of Honolulu.

said to be free from attack were exposed to adults in the laboratory and 219, 285, and 222 eggs, respectively, were laid in them. To determine whether the confinement of different varieties of improved mangoes would throw any light upon their varietal susceptibility, the various combinations indicated in Table XI were placed in jars of ovipositing adults and allowed to remain 24 hours. This experiment was made possible by the gift by the Federal Experiment Station at Honolulu of fruits which had been protected from fruit-fly attack by paper bags. The extent of infestation under these forced conditions shows that the Piri, Brinda Bani, and Divine were least affected. The Divine and Brinda Bani are varieties so little attacked in the open that they are not protected by paper bags during development. It is interesting to note that the Piri, which is one of the very best eating varieties of mangoes grown in Honolulu, is the least susceptible to attack of the varieties used in the experiments with the exception of the Brinda Bani and Divine. The Black Alfonse and Cowasjee Patel grown at the Moanalua Gardens appear equally resistant with the Piri, and from these gardens Mr. S. M. Damon has sent out many superb fruits of these three varieties, which reach maturity uninfested and unprotected.

46. Elengi Tree (*Mimusops elengi*).

The fruits of *Mimusops elengi* grown in Hawaii appear to belong to two varieties. Both are infested as they become fully ripe, but the glabrous variety supports many more larvæ than the pubescent variety (Pl. VIII, fig. 2). The fruits of both have a tough, firm outer shell, a mealy pulp, a proportionally large central stone, and are about three-fourths of an inch long. Of 34 fruits of the glabrous variety gathered from the ground during February only 7 yielded no adults. From the remaining 27 fruits, 355 adults, or an average of about 13 adults per fruit, were reared. Of 15 fruits of the pubescent variety gathered from the ground at the same time, 8 yielded no adults, and 7 yielded 27 adults. From 10 fruits of the glabrous variety 17, 15, 13, 10, 7, 30, 21, 22, 19, and 2 adults were reared.

47. Mock Orange (*Murraya exotica*).

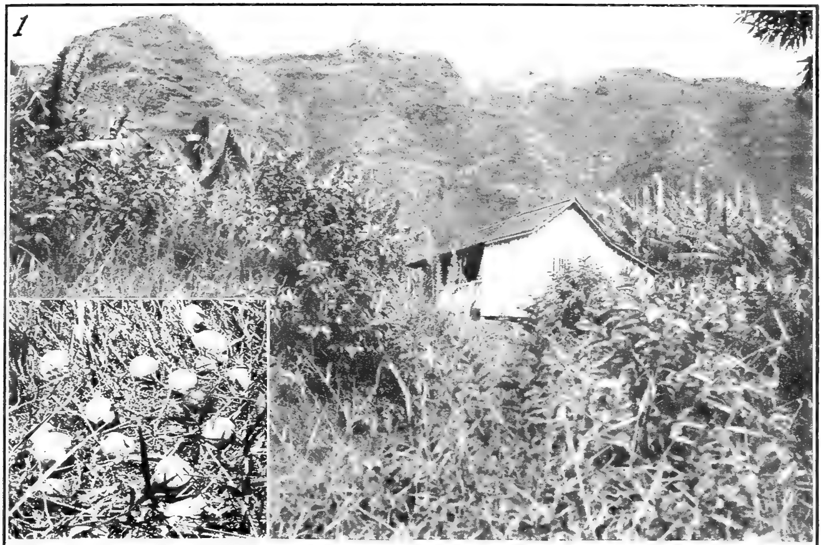
The small fruits of the mock orange or orange jessamine (*Murraya exotica*) are preferred hosts (Pl. VIII, fig. 4). From 1 to 3 larvæ only are able to mature in a single fruit. Of 111 fruits gathered during March, 1914, 26 were not infested. From the remaining 85 fruits 148 adults were reared; 10 fruits yielding, respectively, 1, 1, 2, 3, 2, 1, 1, 2, 1, and 3 adults.

48. Banana (Pl. XIV, XV, XVI).

The banana export trade of the Hawaiian Islands amounted to 256,319 bunches during the year ended June 30, 1915. For the most part, the shipments were composed of the chief commercial variety of Hawaii, the Chinese banana (*Musa cavendishii*), although a small number of Bluefields (*Musa sapientum*) entered into the shipments. With the appearance of *C. capitata* in Hawaii, it became imperative, therefore, to determine to what extent, if any, this established trade jeopardized the mainland fruit interests. Previous to the experimental work in Hawaii, the banana had been classed among the host fruits of *C. capitata* by officials of the Australian Commonwealth and by Gowdey [1] of British East Africa without modifying statements.

A critical review of the Australian literature seems to indicate that the positive references to the presence of *C. capitata* in bananas should be questioned, as it is more than probable that the similarity in the appearance of fruit-fly larvæ has led to a con-

[1] In a letter to the writers dated July, 1916, Gowdey writes that his previously reported rearing of *C. capitata* from bananas was made under abnormal or laboratory conditions. He succeeded in rearing adults from overripe bananas infested in the laboratory. He was not attempting to prove the immunity, or otherwise, of this fruit when green, although sufficiently ripe for the trade, and makes no claim that under field conditions the banana is a host fruit of this fly.

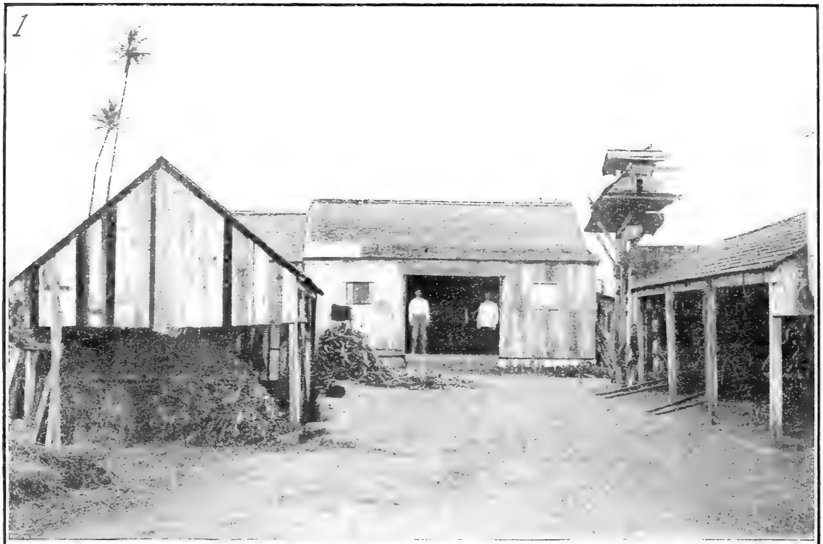


2

REGULATING MEDITERRANEAN FRUIT-FLY CONDITIONS.

As a result of the regulation of the Federal Horticultural Board the unsanitary fruit-fly conditions about banana plantations have been corrected. FIG. 1.—A small Chinese banana plantation. At present, such guava bushes as are shown, and all other host plants about or in plantation from which fruit is shipped, are cut sufficiently often to prevent fruiting, thus removing the opportunity for fruit-fly larvæ emerging from fallen fruit (see insert) to become attached as pupæ to wrapping material and be transported to California. FIG. 2.—General surroundings of small banana plantations in Kalihi Valley, Oahu, from which fruit is shipped to California. The fruit fly is thoroughly entrenched on all the mountain slopes. (Original.)

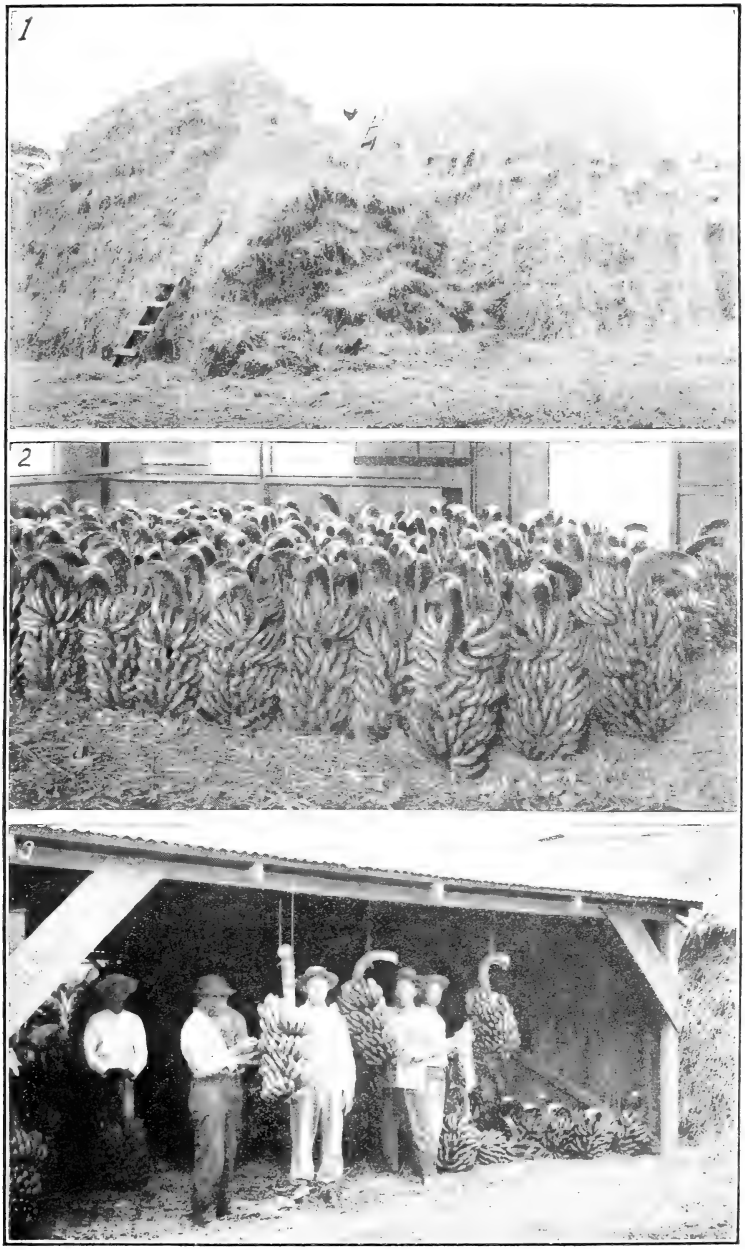
1



2

THE MEDITERRANEAN FRUIT FLY AND THE BANANA INDUSTRY.

FIG. 1.—Typical Chinese house and packing shed at small banana plantations. The rice straw and dried banana leaves used for wrapping all export fruit are stored in open sheds similar to one illustrated to left of view. FIG. 2.—In a bluefield banana plantation at Hilo. Note the dead dried leaves hanging to the trees; when these are thoroughly dry they are cut and stored for wrapping export fruits. (Original.)



THE MEDITERRANEAN FRUIT FLY AND THE BANANA INDUSTRY.

FIG. 1.—Rice straw stacked in the open to be used as wrapping material for export bananas. FIG. 2.—Chinese bananas cut and cleaned, waiting inspection by officer of Federal Horticultural Board. FIG. 3.—Chinamen remove all split, overripe, and bruised fruits as the bananas are brought to the packing sheds from the field. Each bunch is thus cleaned previous to inspection as a safeguard to mainland interests. (Original.)

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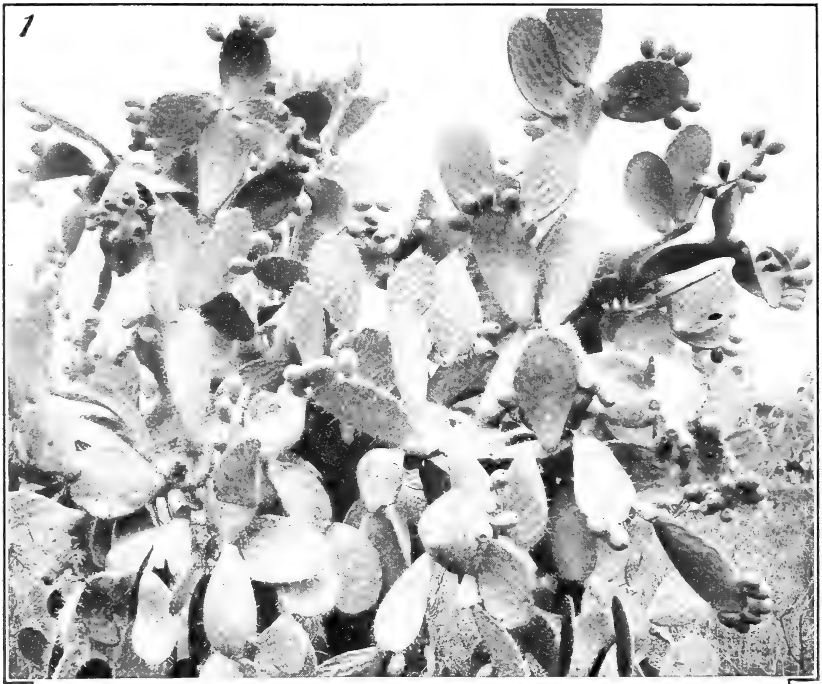

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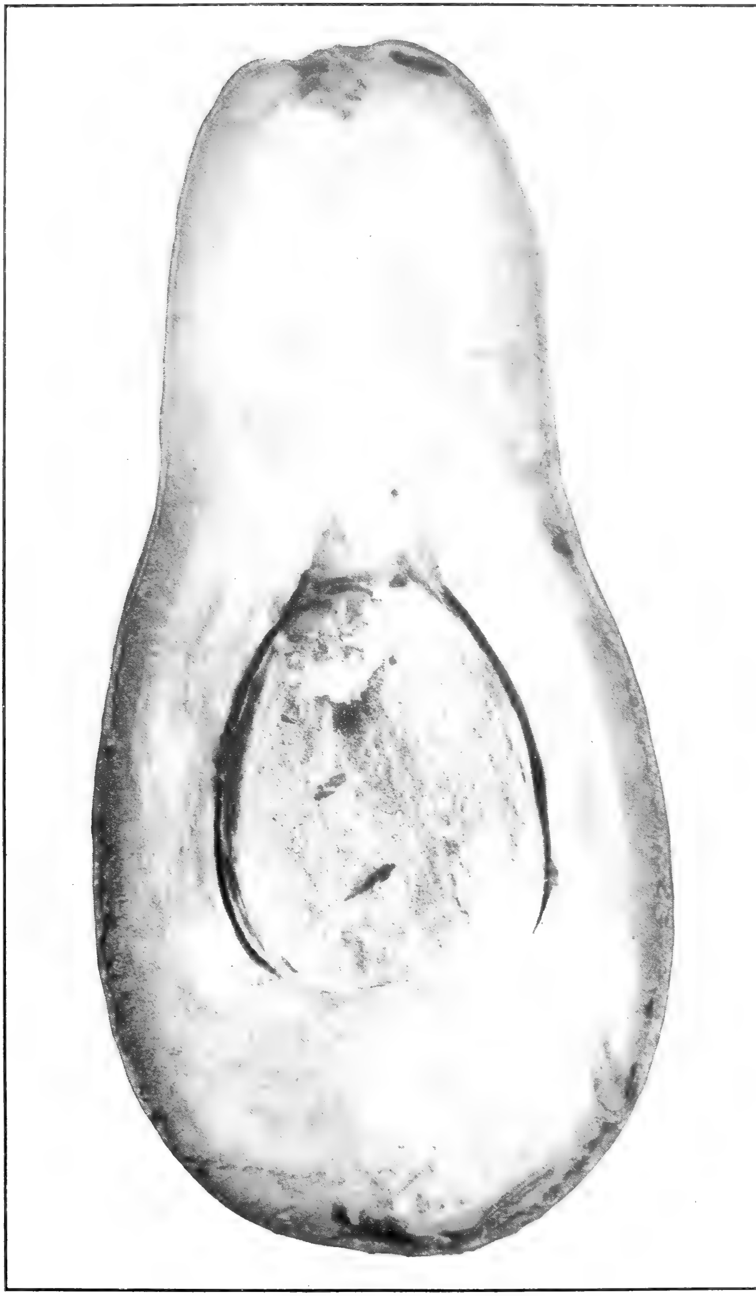
THE PRICKLY PEAR AS A HOST FRUIT OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—Heavily fruiting plant growing on dry arid and waste lands of the Island of Hawaii. In many places this wild host, with the spiny Acacia, forms dense thickets in which the fruit fly can breed. FIG. 2.—A sample of dense growth of prickly pear along the road near Kailua, Hawaii. The seed pods of the algaroba tree (*Prosopis juliflora*) are not infested. (Original.)



THE AVOCADO OR ALLIGATOR PEAR AS A HOST OF THE MEDITERRANEAN FRUIT FLY.

Cross section of improved fruit. Note slight infestation at stem and blossom ends. Infestation is not always general and usually does not interfere with local consumption. The slight infestations, however, have forced this fruit into the quarantine list, thereby ruining a profitable and growing export trade. (Original.)

fusion of other fruit-fly species, known definitely to attack bananas, with *C. capitata*. Illingworth, in 1913, reared the banana fruit fly (*Dacus curvipennis* Frogg.) from larvæ taken in Sydney from bananas imported from Suva. Lea, in Tasmania in 1908, thoroughly familiar with the Mediterranean fruit fly as a result of the campaign for its eradication about Launceston, states that the Queensland fruit fly (*Dacus tryoni* Frogg.) only was found in bananas imported into Tasmania, and does not list this fruit among the host fruits of *C. capitata*. Broun states that, in 1906, *Dacus tryoni* was the only fruit fly reared from bananas imported during February and March into New Zealand from Fiji and Rarotonga. In the report of the biologist of Western Australia in 1898 we read that a consignment of 50 cases of bananas supposed to have originated in Fiji, but more likely having been transhipped to Sydney from an original source in Queensland, had been destroyed at Freemantle because found infested by the Queensland fruit fly. Quinn, in 1907, writes "after seven years experience with bananas * * * we have not yet found the maggots in green bananas. If green when arriving here (South Australia), how very green indeed must they have been when cut from the trees about three weeks previous." French, of Victoria, appears to be the only person in Australia who definitely makes the statement that he has reared *C. capitata* from bananas exported from Queensland into Victoria. Yet Tryon, of Queensland, in a conversation with the senior writer in 1913, stated that *C. capitata* had never been taken in the banana fields of Queensland. The inclusion of the banana among the fruits infested by *C. capitata* and intercepted at the entry ports of New Zealand by Kirk seems to have been an editorial error, as already pointed out in the paper on the banana as a host referred to below. From the foregoing references, it is possible to assume that the results obtained by the writers in Hawaii, where fruit-fly attack is as severe as anywhere, will be verified when opportunity is presented for such careful experiments in other countries as the commercial value of this fruit warrants. Because of the controversial statements of French and Severin it is desirable that Australian entomologists publish data secured in field experiments.

Those particularly interested in the status of the banana as a host fruit are referred to a paper [1] already published by the writers, giving experimental data from which the following conclusions were drawn:

Since the Mediterranean fruit fly (*Ceratitis capitata* Wied.) has not been found infesting the Chinese banana (*Musa cavendishii*) or the Bluefield banana (*Musa* sp.) during the three years that the Federal Government has had charge of the inspection of export bananas in the Hawaiian Islands, it is evident that some reason exists for this practical immunity. This is the more apparent since adult flies of both sexes have been found present in all parts of banana plantations, and surrounding fruits known to be hosts have been heavily infested.

This immunity is shown to be due to the fact that neither the egg nor the nearly hatched larva of the fruit fly can survive in the tannin-laden peel of green, though mature, fruit. In fact, the copious and sudden flow of sap from egg punctures made by fruit flies in unripe bananas renders the successful deposition of eggs in such fruits difficult and rare.

The fact that not 1 of 1,044 fruits of the Chinese banana ripening singly and prematurely among bunches growing in the field, and upon which, as in the case of other host fruits, one might expect gravid females to concentrate their attention for the purpose of oviposition, has been found to be infested, leads to the conclusion that even ripe bananas are not desired as host fruits by adult fruit flies under Hawaiian conditions. On the other hand, the rearing of flies from the ripe and yellow fruits of the thin-skinned Popoulu variety, as well as from ripe fruits of other varieties under forced and unnatural conditions, leads to the equally acknowledged fact that ripe bananas in the field may serve as hosts and should therefore be properly guarded against in all quarantine work.

From the facts stated, the writers believe that bunches of any variety of bananas [2] now growing in the Hawaiian Islands, when properly inspected for the removal of

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[1] Back, E. A., and Pemberton, C. E. Banana as a host fruit of the Mediterranean fruit fly. Jour. Agr. Research, v. 5, p. 793-804. 1916.

[2] As an added precaution against the spread of *C. capitata* to the mainland, cooking bananas of all types are excluded from the trade.

prematurely ripe, cracked, or partially decayed fruits, offer no danger as carriers of the Mediterranean fruit fly, provided they are wrapped and shipped in accordance with the demands of the trade and the Federal regulations.

In addition to the data already presented by the writers, on the immunity of bananas during a 10-day period after the fruit is sufficiently mature for shipment during the summer months, other experimental work has been carried out by H. F. Willard under the writer's direction. This experimental work in detail emphasizes so well the immunity of well-grown bananas still attached to the tree but green in color, although many fruits on the same bunch have either cracked or ripened, that portions of the data are given herewith. The hands of fruit are numbered from the stem end of the bunch.

On November 30, 1915, 14 bunches of Chinese bananas marked in the field at Moiliili for shipment within two days to California were requisitioned and held uncut for experimental work to determine how long during the winter months the bunches could hang after they were sufficiently ripe for the export trade and still ward off attack. A wire-screen cage containing 300 adult flies was placed over one bunch December 13–15, and three days after its removal an examination of the 131 fruits on the bunch, all green in color, showed 108 fruits to be free from attack. Of those attacked 20, 1, and 1 had respectively,3, 1, and 4 punctures, all of which contained no eggs and were more or less superficial; a single puncture in the remaining fruit contained two living first-stage larvæ which later died.

A second bunch from which there had been cut on December 22 1 sound yellow fruit, on December 27, 2 sound and 2 cracked yellow fruits, and on December 29, 3 cracked yellow fruits, was caged on the last date with 300 adults. On December 31, or one month after the fruit was sufficiently ripe for shipment, the cage was removed and on January 3 examined with the following results:

Hand 1: 13 fruits; 7 green and puncture free. Six yellow, 2 puncture free; 1, 1, and 2 had, respectively, 4, 2, and 1 empty punctures.
Hand 2: 15 fruits; 10 green and puncture free. Five yellow, 2, 1, 1, and 1 had 0, 2, 1, and 9 punctures. Punctures empty but ones which contained 2 first stage larvæ that soon died.
Hand 3: 15 green puncture-free fruits.
Hand 4: 14 green fruits; 12 puncture free, 2 had 1 empty puncture each.
Hand 5: 9 green fruits; 7 puncture free, 2 had 1 empty puncture each.
Hand 6: 12 green fruits; 11 puncture free, 1 had 1 empty puncture.
Hand 7: 14 green fruits; 13 puncture free. One fruit had been bruised, so that it was yellow and had begun to decay on one side; it had 7 punctures, of which 2, 2, 1, and 2 contained 6, 1, 4, and 0 eggs, respectively. From this fruit 4 adult flies were reared.
Hand 8: 7 green fruits; 5 puncture free, 1 with 3 empty punctures, and 1 with 1 empty and 3 dead and 1 living first-instar larvæ. Living larvæ died in puncture.

A third of the bunches marked November 10 was caged with 300 adults on January 5, after 43 yellow bananas had been cut from the bunch. On January 7 the cage was removed and the bunch cut. An examination made on January 11 gave the following results:

Hands 1 and 2: Fruits had ripened and been cut before caging.
Hand 3: 4 yellow fruits, 3 puncture free. Remaining fruit had 2 punctures with eggs and eggshells. No adults were reared though the fruit was held over sand.
Hand 4: 8 yellow fruits, 5 puncture free; 1, 1, and 1 fruits had 3, 1, and 1 empty punctures.
Hand 5: 12 yellow fruits, 9 puncture free; 1, 1, and 1 had 3, 2, and 1 empty punctures, respectively.
Hand 6: 13 fruits, 12 green and 1 yellow; no punctures.
Hand 7: 12 green fruits, 11 puncture free; 1 had 2 empty punctures.
Hand 8: 11 green fruits, 9 puncture free; 2 had 1 empty puncture each.

The results of the foregoing experiments, together with others on file, strengthen the conclusions quoted above that bananas cut, wrapped, and shipped according to trade and Federal regulations are not a source of danger as carriers of *C. capitata.* Particular attention is called to the very slight infestation secured under forced conditions, even among fruits actually turning yellow on the tree. Many hundred adults would have been reared from favored host fruits similarly caged with adults.

49. *Noronhia emarginata.*

Noronhia emarginata is a native fruit of Madagascar and Mauritius. The writers have never found it infested, but Mr. E. M. Ehrhorn reared 24 adults from a sample of fruit during July, 1912. Mr. Ehrhorn is also authority for the rearing of adults from fruits grown on Kauai.

50. *Ochrosia elliptica.*

The shrub *Ochrosia elliptica* is grown because of the ornamental value of its scarlet fruits. These are occasionally infested. Thirty adult flies were reared from one lot of 12 fruits maturing in the Punahou district of Honolulu, and 8 from one fruit grown at Waikiki.

51. Prickly Pear (*Opuntia vulgaris*).

Although the prickly pear (*Opuntia vulgaris*) grows wild (Pl. XVII) on waste arid lands in Hawaii, it is not a preferred host. From 23 overripe fruits taken from the ground during August, 1912, on Punchbowl, only 15 flies were reared, while no flies were reared from 28 similar fruits gathered at the same time. No flies were reared from 29 lots totaling 254 fruits collected in Pauoa, Palola, Makiki, Moanalua, and Kalauao during September–December, 1912. These fruits were all ripe, many too ripe to remain erect on the plant, and some had fallen to the ground. From 8 fruits ripe, but erect on the plant, cut from plants on Punchbowl close to the Federal Experiment Station, 8 flies were reared; 10 fruits taken from the ground near the top of Punchbowl at the same time (September, 1912) yielding only 1 fly. Of 8 lots of ripe fruits gathered from plants during December, 1914, from Ewa, Fort Shafter, Kalauao, Red Hill, Salt Lake Road, upper and lower Palolo and Manoa Valleys, totaling 118 fruits, only 1 lot of 5 fruits from Ewa yielded 2 adults.

Compere reports the prickly pear about Malaga, Spain, to be infested by *C. capitata.*

52. Passion Vine (*Passiflora coerulea*).

The fruits of only one species (*Passiflora coerulea*) of passion vines have been found infested by *C. capitata* in Hawaii. Infestation is by no means severe. At Haiku, island of Maui, a search among several hundred ripe fruits proved only two fruits to have been infested, and from these six adults were reared. While numerous fruits of different sizes have been found deformed by punctures on Oahu no adult flies have been reared. It is doubtful if this passion vine supports *C. capitata* except when growing luxuriantly in shaded localities.

Fruits of *Passiflora quadrangularis*, *edulis*, *laurifolia*, *alata* and *foetida* have not been found infested. The common water lemon (*P. laurifolia*) found upon the markets of Hawaii is impervious to attack when ripe, as proved by hanging fruits in jars of adult flies.

53. Avocado (*Persea gratissima*).

The avocado (*Persea gratissima*), palta, or alligator pear as it is sometimes called (Pl. XVIII), is one of the host fruits of *C. capitata* that become infested, if at all, late in their development. In fact, the nature of its infestation for most horticultural varieties is so obscure that the general belief prevails that avocados are free from attack. Previous to the introduction of *C. capitata* in Hawaii a small and growing export trade was being developed and, because of the excellence of the improved Hawaiian avocado,

it promised to become a financial asset to the islands. Even since the quarantines of the Federal Horticultural Board stopped shipments of avocados to the mainland of the United States shipments have been made to the Philippine Islands in cold storage. The following data are the first ever published on the infestation of avocados and are given here to refute arguments for reestablishing the avocado trade on its former basis:

There are many horticultural varieties of the avocado growing in Hawaii, but there appears to be little difference in their degree of susceptibility to attack. The nutmeg or Guatemala variety is the only one free from attack when growing uninjured. Under forced laboratory conditions adults can not oviposit through its unusually thick rind. The skin of all other varieties of avocados, whether very thin or of usual toughness, can be punctured by the adult fly, as proved by the examination of many fruits. The avocado, like the ordinary pear, is best if picked when still hard and allowed to ripen in storage.

If left on the tree too long, the fruits drop and soften on the ground. With most varieties it is not until the fruits are mature enough for gathering or dropping that adults oviposit in them. As they are sufficiently soft for eating purposes within two to four days after being cut from the tree, the larvæ are still very young, if not just hatched, and are to be found feeding close to the tough leathery rind. Their presence, therefore, is seldom observed by those eating avocados served whole or cut in half to be eaten with a spoon. When served cut in small pieces, with mayonnaise, the paring process usually crushes the small larval burrows on the outer surface of the pulp and the larvæ go to the table unobserved. As thousands of larvæ are thus consumed yearly in Honolulu alone, it may be well to state that they do no harm.[1] Fruits in which the larvæ have become well grown are usually too soft for eating purposes.

Several thousand fruits have been examined carefully by the removal of the skin. Of 1,027 fruits thus examined, picked from the trees at Wahiawa and representing 10 separate lots of fruit, 173, or 16.8 per cent, were found to contain eggs or larvæ; of 384, representing six lots of fruit picked from the ground at Wahiawa, 57 fruits, or 14.8 per cent, were infested. Notes on certain uninfested fruits show that of the green varieties 354 were thick skinned and 75 were thin skinned; of the purple varieties, 254 were thick skinned and 101 were thin skinned. Of 120 infested fruits, 42 and 12 were green varieties with thick and thin skins, respectively, while of the purple varieties, 32 and 34 were thick skinned and thin skinned, respectively. The considerably larger proportion of thin-skinned purple fruits found infested agrees in the main with observations on similar fruits found on the markets. Eleven purple fruits of an early thin-skinned variety picked from the tree in the Makiki district of Honolulu had an average of over 41 punctures in the skin, no fruit having less than 12 or more than 119 punctures. A fruit of a second thin-skinned purple variety grown by Mr. G. P. Wilder, of Honolulu, known to be generally infested if the fruits are allowed to remain on the tree too long, was hung in a jar of adult flies for about 18 hours beside a fruit similar in appearance and degree of ripeness, taken from another tree. An examination after removal of the fruits showed 7 eggs to have been deposited in 1 puncture in 1 fruit while in the Wilder fruit 487 eggs had been deposited in 56 punctures. In a green fruit with a hard, tough skin exposed to adults for 5 hours, 32 eggs were deposited in 14 punctures. One lot of 863 fruits of all varieties gathered by a fruit dealer from trees in upper Manoa Valley and the Punahou district of Honolulu were not infested, but these were picked several days earlier than they might have been picked. Avocados shipped rather green from the islands of Hawaii and Kauai to Honolulu (Oahu) were not found infested, but their freedom from infestation was due to the earliness of their gathering. Ten thin-skinned purple fruits grown at Waikiki and purchased in the market had an average of over 9 punctures per fruit, 1 fruit having 33 punctures and

[1] The writers have personally conducted experiments in which it is estimated persons have eaten 2,000 eggs and young larvae in plums without injurious results.

only 1 being puncture free. Ten thick-skinned green fruits in the market from Kalauao had an average of 6.2 punctures, with no fruit puncture free; 4 of 6 thin-skinned purple fruits taken from the market were puncture free, the remaining 2 fruits having 1 and 3 punctures, respectively. One thick-skinned green fruit picked by the owner and brought to the laboratory as an example of a fine fly-proof variety was found when examined in his presence to contain 230 eggs in 18 punctures. The details of the examinations of many hundred individual fruits are on file and open to those desiring further information on the infestation of avocados at the time they are offered for sale.

In spite of the frequency of infestation as indicated above, the avocado does not appear to be a very satisfactory host for *C. capitata* when one considers its relatively large size and the number of adult flies that can be reared from it. The larval mortality is greater than in many preferred hosts. From thin-skinned purple fruits containing 119, 41, 29, 19, and 37 punctures, 4, 7, 39, 6, and 0 adults were reared. Only 36 adults were reared from a green-skinned variety known to have contained 230 eggs. From 1 fruit that had begun to wither on the tree, an unusual occurrence, 16 adults were reared. Forty-eight is the largest number of adults ever reared from a single fruit by the writers. Of 81 fruits of all varieties known to have been infested when placed separately in jars over sand, 39 produced no adults, while from the remaining 42 fruits 570 adults were reared. No adults were reared from 427 fruits gathered promiscuously and placed in jars without examination to prove them infested.

54. Date Palm (*Phoenix dactylifera*).

Although thousands of fruits of the unimproved date palm (*Phoenix dactylifera*) ripen each year in Hawaii, the writers have found only one instance of infestation. Thirty-five green, but well-grown, dates collected August 11, 1913, at Ainahau, Waikiki, which appeared to have been affected by some disease that rendered them abnormally moist, yielded 2 adults of *C. capitata*. This was probably a chance infestation.

55. Strawberry Guava (*Psidium cattleyanum*).

The strawberry guava (*Psidium cattleyanum*) is a preferred host, and the fruits are usually badly infested. From 96 out of 145 fruits picked March 16, 1913, 364 adults were reared, or an average of 3.8 per fruit. No fruit yielded more than 8 adults. From 500 fruits an average of 4.1 adults were reared during April, 1913. From 90 fruits collected during February, 1916, an average of 4.8 adults per fruit were reared; 15 fruits yielding 1, 3, 2, 11, 7, 7, 6, 5, 9, 7, 6, 2, 8, 6, and 18 adults, respectively.

56–58. Guavas.

The common guavas of Hawaii (*Psidium guayava, P. guayava pomiferum* and *P. guayava pyriferum*) are subject to general infestation. While the guava grows wild up to 4,000 feet elevation and forms dense thickets on the lower levels, even many miles from habitations (Pls. II, III), and is an ever-present source of adult flies, many statements previously published exaggerate the degree of infestation of individual fruits. The writers have never been able to collect samples of 25 miscellaneous fruits without finding some infestation; 14, 18, 15, 17, 10, 10, 10, 24, 7, 6, 6, and 6 fruits collected at 14 places on the windward and leeward sides of Oahu on September 9, 1914, yielded respectively 60, 46, 46, 107, 119, 11, 19, 4, 41, 1, and 2 adults. Each of 62 fruits, except 7, picked ripe from bushes at points along the Tantalus Road yielded adults; from 55 fruits 307 adults were reared. During January, 1916, 75 per cent of all fruits examined along the same road were found infested. From 18 fruits collected May 30, 1913, from bushes near the Libby, McNeil, and Libby Cannery, windward Oahu, at sea level, 423 adults, or an average of 23.5 flies per fruit, were reared. Nine fruits collected between Wahiawa and Haleiwa, Oahu, on January 21, 1912, yielded 96 adults. The writers have never reared more than 34 adults from a single fruit.

That it may be appreciated that, contrary to the belief of many, the wild guavas in the mountains back of Honolulu are a continual source of adult flies, particularly in midwinter, the following records were made:

21 fruits picked on and near the top of Round Top, Tantalus, 1,100 feet elevation, December 19, 1913, yielded 63 adults.
24 fruits from Pauoa Flats, 1,100 feet elevation, December 22, 1913, yielded 69 adults.
42 fruits from rim of Palolo Crater during December, 1913, yielded 362 adults.
22 fruits from top of east ridge, Manoa Valley, 1,000 feet elevation, yielded 100 adults.
50 fruits from head of Palolo Valley, 1,000 feet elevation, on January 2, 1914, yielded 84 adults.

59. Peach (*Prunus persica*).

The peach (*Prunus persica*) is the most preferred of all host fruits grown in Hawaii and in other countries (fig. 3). While excellent peaches have been grown in the islands, at the present time scarcely a peach matures on the lower levels, and usually the fruits are utterly destroyed before they are more than half to three-fourths grown. From 128 fruits, about three-fourths grown, picked from the ground during April, 1913, 2,929 adults, or an average of about 23 adults per fruit, were reared. From 10 of these fruits 34, 12, 25, 8, 49, 78, 64, 17, 6, and 54 adults, respectively, were reared. As many as 90 larvæ have been taken from a single fruit.

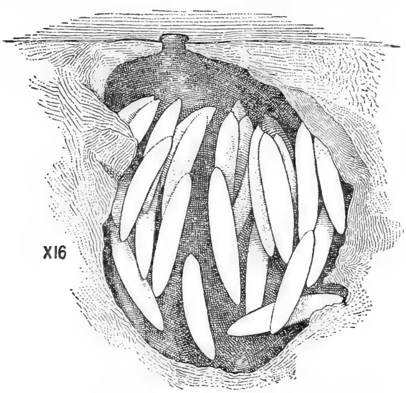


Fig. 3.—Cross section of peach, showing the general shriveling of the walls of the egg cavity and the separation of the eggs. Drawing made 1½ days after oviposition. (Authors' illustration.)

The writers have on file data secured during experimental work on the infestations of several thousand individual fruits, but they throw no additional light on the severity of peach infestation.

60–62. Nectarine (*Prunus persica* var. *nectarina*), Apricot (*Prunus armeniaca*), and Plum (*Prunus* spp.).

Varieties of *Prunus* spp. known as plums, apricots (fig. 4), and nectarines are reported well infested where grown in infested regions. These fruits are imported in season to Hawaii from California and have been easily infested under forced laboratory conditions. It seems probable that they will serve best as hosts when partially grown, as the excessive moisture content of the well-ripened fruits, particularly of such varieties as the Japanese plums, causes a high mortality among young larvæ.

63. Pomegranate (*Punica granatum*).

The writers have never reared *C. capitata* from pomegranate. Mr. O. H. Swezey, of Honolulu, reared an adult identified by the senior writer as *C. capitata* from a fruit partially decayed. The writers have examined many perfect and split fruits without detecting evidences of infestation. Compere records finding infested fruits in Asia Minor, and Trabut in 1901 reports infestation in Algeria.

64. Apple (*Pyrus* spp.).

Only a few apple trees (*Pyrus malus*) are found growing in those regions of Hawaii sufficiently warm for *C. capitata*, hence the writers can offer no observations on the infestation of this fruit occurring in the field. Apples have been found infested in

South Africa and Australia by other investigators. Gurney, of New South Wales, lists the apple among host fruits occasionally infested. Wickens, in 1914, in western Australia, writes that "the apple growers who have been hoping that they would not suffer so severely as growers of soft fruits are now becoming seriously alarmed at the presence of fruit-fly punctures and larvæ in their export varieties of apples. Fortunately the two apple-producing centers of the State (Bridgetown and Mount Baker) are free from the pest." Lounsbury, in South Africa, writes that "ordinarily only peaches, nectarines, and pears are severely infested, but last year apricots, figs, pears, plums, apples, and quinces were almost all attacked." Newman states that in western Australia eggs deposited in undeveloped apples and pears rarely hatch and that if they do the larvæ die. The senior writer found apples grown throughout eastern and southern Spain quite generally infested during 1916.

The writers have used apples extensively in their experimental work and have found them an excellent fruit for securing large numbers of larvæ and eggs for temperature studies. The firmer apples, if not overinfested, serve better than any fruit as a medium for carrying the pest along within the laboratory for considerable periods. Some fruits become too moist and these are not satisfactory. For one type of infestation see Plate I, figure 2, and Plate XI, figure 2.

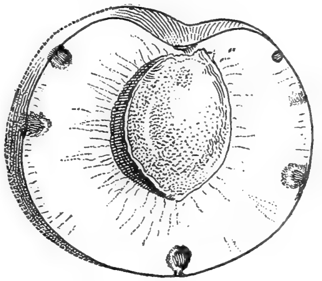


FIG. 4.—Small apricot, natural size, showing eggs of the Mediterranean fruit fly deposited in five places. (Original.)

65. PEAR (*Pyrus* spp.).

There are few pear trees grown in yards in Honolulu. The fruits are generally and badly infested, the interior often becoming badly eaten out by larvæ while the exterior appears unaffected. Often fruits, entirely destroyed, may dry up and remain attached to the tree. Such a fruit is illustrated in Plate VII, figure 2.

66. SANDALWOOD (*Santalum freycinetianum* var. *littorale*).

Adults of *C. capitata* were reared during the summer of 1916 from the fruits of the native sandalwood by Messrs. O. H. Swezy and J. C. Bridwell. The infested material was taken from a tree growing about 50 feet above sea level at Waianae, Island of Oahu.

67. EGGPLANT (*Solanum melongena*).

The eggplant (*Solanum melongena*) has been found infested only once during four years by the writers. One hundred and fifteen fruits of all ages gathered from the vines in the Moiliili market garden during April 26–30, 1914, showed no infestation when examined May 2 to 5 by the removal of the skin. One thousand fruits in all conditions of soundness were examined by the junior writer during November, 1915, by carefully removing the skin from each fruit. In only one fruit were larvæ found. These were well grown, several in number, and in tunnels immediately beneath the skin. Adults of *C. capitata* were reared from these larvæ. The senior writer has personally examined many fields superficially, but has never seen infestation due to either *C. capitata* or *Bactrocera cucurbitae*.

68. WI (*Spondias dulcis*).

The "wi" (*Spondias dulcis*), a native tree of the Society Islands but common to the tropics of both hemispheres, is common in Honolulu and bears heavily. Its fruits are only slightly infested by *C. capitata*. From 200 very ripe fruits gathered on

October 2, 1913, only 7 adults were reared. Four adults were reared from 33 ripe fruits in which many eggs were laid under forced laboratory conditions during December, 1915, and January, 1916. The fruits usually ripen uninfested.

69. Natal Plum (*Terminalia chebula*).

The Natal plum (*Terminalia chebula*) is well infested as the fruits ripen and has proved an excellent source of larvæ for experimental work. From two lots of fruit of 12 pounds each, 2,761 and 2,655 adults, respectively, were reared during October-November, 1915.

70. Tropical Almond or Winged Kamani (*Terminalia catappa*).

The tropical almond or winged kamani (*Terminalia catappa*) is a preferred host. It is one of the most reliable sources for fruit-fly material in the Hawaiian Islands. The pulp, upon which the larvæ feed as the fruit ripens, is scarcely three-eighths of an inch thick. (See Pl. XIX.) Severin obtained from 25 fruits 1,380 larvæ; 98 larvæ from one fruit. The writers have reared many thousands of larvæ for experimental work. From 16 lots of fruit from different Honolulu localities collected during October, 1915, totaling 1,531 fruits, 10,005 larvæ developed. From 3,902 fruits collected from 28 localities during November and December, 1915, only 11,481 larvæ developed. It remains to be seen whether the scarcity of larvæ in the fruits developing during late 1915 was due to the work of parasites or to other causes.

71. Bestill (*Thevetia neriifolia*).

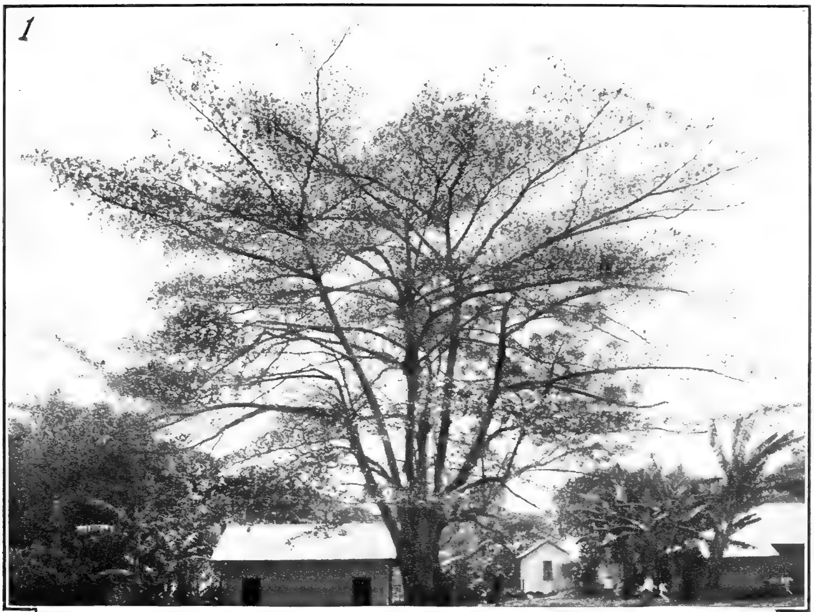
The bestill or yellow oleander (*Thevetia neriifolia*) is never infested until it begins to turn black when ripening. Until then it is excellently protected by its white sticky sap which exudes rapidly from any slight abrasions in the epidermis. The pulp is quite dry and pithy and often escapes infestation, particularly during dry spells. When the fruits ripen very slowly during colder weather and fall to damp shaded spots, as many as 38 adults may be reared from a single fruit. In Bermuda, in the absence of an abundance of other hosts, the Thevetia was found very badly infested with unusually large larvæ during December. In Honolulu many fruits ripen uninfested.

72. Grape (*Vitis labrusca*).

The Isabella grape (*Vitis labrusca*) is the only grape grown in any quantity in Hawaii. The fruits mature and are sold on the markets and appear to be entirely free from fruit-fly attack. This variety of grape is, however, subject to slight attack. One fruit inspector detailed to collect suspicious-appearing fruits brought to the office 978 berries as the result of a 4-day search. A careful examination by H. F. Willard of these with a hand lens revealed five well-grown larvæ in two lots of fruit totaling 201 berries. Two of the larvæ died, but the other three developed into adults identified as *C. capitata*.

Newman, in western Australia, states, in 1912, that he found *C. capitata* frequently in grapes, yet in 1914 he writes that at Crawley little or no sound fruit had been picked for years except grapes. Lounsbury, in 1907, states that he found grapes only slightly infested in South Africa. Whatever the degree of infestation is elsewhere, in the Hawaiian Islands it is so slight that it is never noticed in the vineyards where fruit is grown for the production of wine or where fruits are ripening for table purposes on isolated vines growing in badly infested districts of Honolulu. Excellent bunches of grapes are picked within a few feet of badly infested peaches.

1



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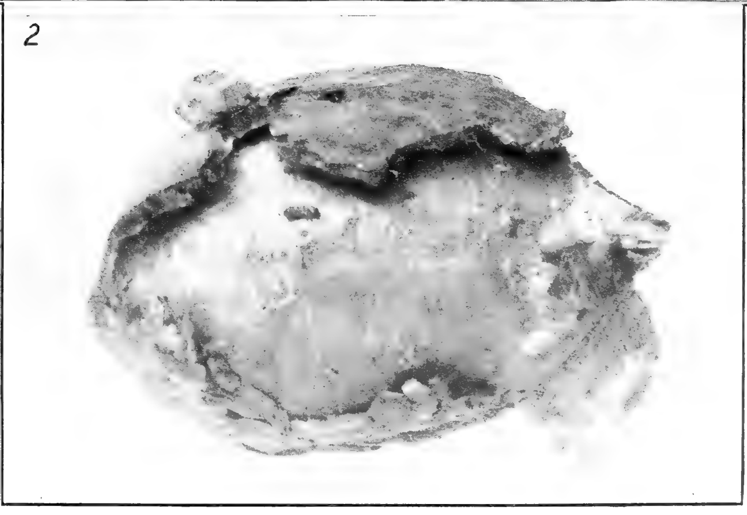

A HOST FRUIT OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—A large winged kamani tree (*Terminalia catappa*) with a 6-foot man standing beneath for comparison. The fruits of this species are badly infested and, because they ripen and fall in large or small numbers during the entire year, greatly interfere with successful clean-culture work. FIG. 2.—The nuts are from 2 to 2.5 inches long; the fruit-fly larvæ feed only on the thin pulp covering the nut. (Original.)

LIFE HISTORY AND DESCRIPTION.

THE EGG.

DESCRIPTION.

The eggs (figs. 3–6) are glistening white, about 0.945 mm. long, elongate elliptical, and often more convex on the dorsal side.

DURATION OF EGG STAGE.

Martelli gives the duration of the egg stages at Portici, Italy, as 2 days in August and from 4 to 5 days in October. Newman states that in Western Australia eggs hatch in from 2 to 4 days during summer and in from 14 to 19 days during winter. Mally, in South Africa, found the egg stage to be from 2 to 4 days in midsummer. Other data have been published but give no additional information and, being unaccompanied by temperature records, may be omitted. Newman appears to be the only investigator who has made an effort to secure data for the winter period.

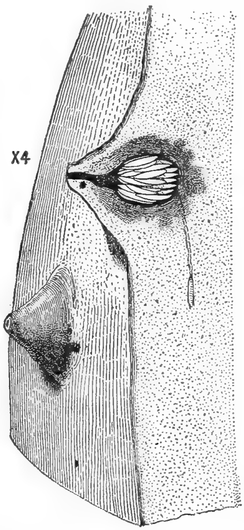

Fig. 5.—Section of grapefruit rind, showing two egg cavities, one in cross section. Drawing made one week after fruit was picked. Note conical elevation about the egg cavities left by the withering of the rind; also the thickened walls of the egg cavity and the single larval channel in the rag. (Authors' illustration.)

In Honolulu, or littoral Hawaii in general, the length of the egg stage is very short, and agrees with the minimum periods indicated by writers in other countries. In Table XII are recorded data on observations on 4,066 eggs secured at Honolulu, which indicate that the largest number of eggs hatch in from 2 to 3 days after deposition during the hottest weather. At a mean temperature of 79° F., 208 eggs hatched in from 49 to 51 hours after deposition, while 79 hatched in from 52 to 53 hours, and 3 in from 53 to 54 hours. At a mean temperature of 78.9° F., 134 eggs hatched between 49 and 54 hours after deposition, although 12 eggs deposited at the same time did not hatch until from 66 to 72 hours later. At a mean of 71° F., 695 eggs hatched within 72 hours, while 3 hatched in from 120 to 144 hours, or about 6 days after deposition. At a mean of 70.5° F., 437 eggs hatched in from 77 to 83 hours after deposition and 227 after a period of 83 to 91 hours had elapsed. At a mean of 69.8° F.,

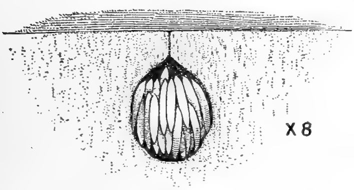

Fig. 6.—Cross section of peach, showing egg cavity of the Mediterranean fruit fly with eggs. Drawing made directly after oviposition. (Authors' illustration.)

356 eggs hatched after a period of from 84 to 91 hours, 216 after 91 to 92 hours, 127 after 92 to 93 hours, 33 after 93 to 94 hours, 8 after 94 to 95 hours, 5 after 95 to 96 hours, and 3 after 104 to 106 hours. Eighty-eight eggs hatched between 4 and 4.5 days after deposition at a mean temperature of 68.7° F.

TABLE XII.—*Duration of the egg stage of the Mediterranean fruit fly at Honolulu under normal conditions.*

Number of eggs under observation.	Eggs deposited.	Eggs hatched.	Average mean temperature.
			°F.
88	Jan. 21–22, 4 p. m. to 10 a. m	Jan. 26, 6 a. m. to 3 p. m	68.7
350	Mar. 9, 10 a. m. to 12 m	Mar. 12–13, 4.30 p. m. to 8 a. m	70.2
102	Mar. 27, a. m. to 1 p. m	Mar. 30, a. m	71
695	....do	Mar. 30, a. m., to Mar. 31, a. m	71
28	....do	Mar. 31–Apr. 1, 9 a. m. to 8 a. m	71
3	....do	Apr. 1, 2 p. m. to 8 a. m	71
176	May 12–13, 3 p. m. to 12 m	May 15, a. m	75
243	....do	May 15–16, 2 p. m. to 8 a. m	75
44	June 18, 1.30 to 3.30 p. m	June 20–21, 6 p. m. to 8 a. m	77
90	June 19, 10 a. m. to 1 p. m	June 21–22, 6 p. m. to 8 a. m	76.6
77	June 20, 9 a. m. to 4 p. m	June 22–23, 6 p. m. to 7.30 a. m	77
63	June 24, 1.30 to 4.30 p. m	June 26–27, 4.30 p. m. to 6 a. m	77
134	July 15, 3.30 to 4.30 p. m	July 17, 4.30 to 6 p. m	78.9
128	....do	July 17, 6 to 8 p. m	78.9
20	....do	July 17, 9 to 10 p. m	78.9
12	....do	July 18, 10 a. m. to 4 p. m	78.3
208	Aug. 24, 10.30 to 11.30 a. m	Aug. 26, 11.30 a. m. to 1 p. m	79
79	....do	Aug. 26, 1 to 2 p. m	79
3	....do	Aug. 26, 2 to 3 p. m	79
47	Sept. 9, 3 to 4 p. m	Sept. 11, 3 to 9 p. m	79.7
101	Nov. 13–14, 4 p. m. to 9 a. m	Nov. 16, 2 to 6 a. m	75.5
10	....do	Nov. 16, 6 to 11 a. m	75.5
356	Dec. 15, 11 a. m to 1 p. m	Dec. 18–19, 11 p. m. to 6 a. m	69.8
216	....do	Dec. 19, 6 to 7 a. m	69.8
127	....do	Dec. 19, 7 to 8 a. m	69.8
33	....do	Dec. 19, 8 to 9 a. m	69.8
8	....do	Dec. 19, 10 to 11 a. m	69.8
5	....do	Dec. 19, 11 a. m to 12 m	69.8
3	....do	Dec. 19, 8 to 10 p. m	69.8
437	Dec. 16, 11 a. m. to 1 p. m	Dec. 19, 4 to 10 p. m	76.5
227	....do	Dec. 19–20, 10 p. m. to 6 a. m	70
4,066			

While eggs hatch in from 2 to 6 days after deposition in any fruit-growing section in the Hawaiian Islands, they may require a much longer period for development under colder weather conditions. In the course of experimental work, the writers have secured data showing that under varying conditions of temperature the duration of the egg stage may be extended to at least 25 days. In Table XIII data of special interest, as indicating how dependent embryonic development is upon temperature, are recorded.

All of 131 eggs one day old when placed at Puulehua, where the temperature ranged between 39° and 89° F., with a mean of about 52° F., were still unhatched after 16 days at Puulehua, after which they were taken to Kealakekua, where they hatched the following day, or when 18 days old.

Twenty-three eggs deposited in apples at Kealakekua, Kona, Hawaii, at about 1,100 feet elevation, on February 9–10, 1915, and taken on February 11 to the summit of Hualalai, 8,250 feet eleva-

tion, where the temperature ranged between 30° and 62° F., with a mean of 46° F. for the period of observation, were still unhatched after exposure for 14 days. After 14 days on Hualalai eggs were carried in their host to Kealakekua and there hatched on February 27, or 17 to 18 days after they were deposited.

Additional information on the duration of the egg stage has been secured under cold-storage conditions. Eggs hatch in refrigeration at temperatures ranging between 54° and 62° F. Five eggs deposited August 15–16 and placed in a refrigerator at 54° to 57° F. on August 16 hatched within the refrigerator on August 23, or in from 7 to 8 days after deposition; 19 eggs deposited at the same time were removed unhatched on August 23 but hatched on the 24th, outside the refrigerator, or 8 or 9 days after deposition. A single egg also deposited on August 15–16 and similarly placed at 54° to 57° F. had not hatched by August 30, when it was removed to normal temperature, where it hatched within 24 hours, or 14 or 15 days after deposition. Thirty-two eggs deposited on July 15–16 and placed on July 16 at 58° to 62° F. hatched in the refrigerator on July 20 or in from 4 to 5 days after being deposited, whereas 6 eggs of the same lot were unhatched in storage on July 24, after which they were removed to normal temperatures where they hatched on July 25, or 7 to 8 days after deposition. Eggs deposited on February 11–12, and placed at 48° to 52° F. on February 12, failed to hatch at this temperature, but 20 removed after 14 days hatched within 16 to 17 days after deposition; 11 removed after 19 days hatched within 21 to 22 days after deposition; while 1 removed after 22 days of refrigeration hatched on March 8, or 24 to 25 days after deposition. The examination of a second lot of fruit containing 1,853 eggs, deposited during a 24-hour period before they were placed at a temperature of 48° to 53° F., showed that one egg hatched in storage 18 days after the inward date and after 24 and 27 days of refrigeration 64 and 56 first-instar larvæ had hatched and died in the punctures. Of these 1,853 eggs, 1,014 removed after refrigeration for 18 to 27 days were dead; of 115 removed to normal temperatures after refrigeration for 16 days, 35, 25, and 9 hatched in 17, 18, and 19 days, respectively, after deposition. Eggs deposited during a 4-hour period were placed immediately at 49° to 56° F.; after refrigeration for 21 days, 1 living and 7 recently dead first-instar larvæ and 51 unhatched eggs were found. Of other eggs deposited at the same time but held at normal temperatures for from 44 to 47 hours before being placed in storage, 8, 12, and 48 had hatched after refrigeration for 16, 19, and 21 days. One egg, two days after deposition, was held in storage at a temperature of from 40° to 45° F. for 20 days (June 27 to July 17), when it was removed to normal temperatures where it hatched three days later, or 25 days after deposition. One egg

placed in storage at 26° to 30° F. when one day old, and held at this temperature for 7 days, hatched three days after removal, or 11 days after deposition.

TABLE XIII.—*Duration of the egg stage of the Mediterranean fruit fly under low temperature conditions.*

Number of eggs under observation.	Eggs deposited.	Cold-storage dates.		Dates of hatching.	Number of days in storage.	Length of egg stage.	Temperatures.	
		Inward.	Outward.				Range in storage.	Mean outside storage.
							°F.	°F.
10	July 6, 1913	July 7	July 8	July 9	1	3	26–30	78
4	....do	...do	July 9	July 10	2	4	26–30	78
1	....do	...do	...do	July 12	2	6	26–30	78
2	....do	...do	July 8	...do	1	6	26–30	78
388	Nov. 3, 1914	Nov. 4	Nov. 8	Nov. 10	4	7	26–30	76.5
6	June 30, 1913	July 2	July 8	July 9	6	9	26–30	77
1	Nov. 3, 1914	Nov. 4	Nov. 11	Nov. 14	7	11	26–30	76.5
520	Sept. 25, 1914	Sept. 26	Sept. 28	Sept. 29	2	4	32	77.6
216	....do	...do	Sept. 30	Oct. 2	4	7	32	77.6
1	....do	...do	Oct. 5	Oct. 7	9	12	32	77.5
21	Sept. 7, 1914	Sept. 9	Sept. 17	Sept. 19	8	12	33–34	79.5
4	....do	...do	...do	Sept. 21	8	14	33–34	78.9
242	Nov. 16, 1914	Nov. 17	Nov. 25	Nov. 28	8	12	36	69.5
5	....do	...do	Nov. 27	Dec. 1	10	15	36	70.4
5	July 4, 1913	July 5	July 8	July 9	3	5	33–38	77.2
11	....do	...do	July 9	July 12	4	8	33–38	77.4
13	....do	...do	July 16	July 18	11	14	33–38	78.2
1	July 17, 1913	July 18	Aug. 1	Aug. 4	14	18	33–38	78.9
1	June 25, 1913	June 27	June 30	June 30	3	5	38–45	77.8
3	....do	...do	...do	July 2	3	7	38–45	77.6
7	....do	...do	July 5	July 6	8	11	38–45	77.3
1	....do	...do	July 8	July 10	11	15	38–45	77.4
6	....do	...do	July 14	July 15	17	20	38–45	77.7
1	....do	...do	July 17	July 18	20	23	38–45	77.9
1	....do	...do	...do	July 20	20	25	38–45	77.8
20	Feb. 11–12, 1915	Feb. 12	Feb. 26	Feb. 28	14	16–17	48–53	69.8
11	....do	...do	Mar. 3	Mar. 15	19	21–22	48–53	70.5
1	....do	...do	Mar. 6	Mar. 8	22	24–25	48–53	70.6
19	Aug. 15–16, 1914	Aug. 16	Aug. 23	Aug. 24	7	8–9	54–57	79.1
5	....do	...do	(1)	Aug. 23	7	7–8	54–57	79.1
1	....do	...do	Aug. 30	Aug. 31	14	14–15	54–57	79.1
32	July 15–16, 1914	July 16	(1)	July 20	4	4–5	59–62	79.5
6	....do	...do	July 23	July 24	7	7–8	59–62	79.5
172	Sept. 9, 11 a. m. to 2 p. m.	Sept. 9, 3 p. m.	(1)	Sept. 16	7	7	60–64	79.2
23	Feb. 9–10, 1915	[2] Feb. 11	Feb. 25	Feb. 27	....	17–18	[4] 30–62	69.4
131	Feb. 20, 1915	[3] Feb. 21	....	Mar. 6	....	14	[5] 39–89	67.8
1,720								

[1] Fruit not removed. Eggs hatched in storage.
[2] Not placed in cold storage, but exposed to normal tmperatures at summit of Mount Hualalai, 8,200 feet elevation.
[3] Not placed in cold storage, but exposed to normal temperature at Puulehua, about 4,500 feet elevation.
[4] Mean temperature about 46° F.
[5] Mean temperature about 70° F.

These data, together with those recorded in Table XIII, demonstrate the great variation, from a fruit-fly standpoint, in the duration of the egg stage.

THE LARVA.

DESCRIPTION.

A clear idea of the general shape of the larva or maggot of the Mediterranean fruit fly can be gained by reference to text figures 7 and 8, and Plate XIII, figure 1. When first hatched from the egg, the larva is about 1 mm. long but increases in size to from 7–8 mm. long when full grown. Each larva passes through three well-defined

instars. While normally white in color, it may appear creamy yellow, pink, or with colorations of red or black, according to the nature of its food, which shows through the semitransparent body walls.

First larval instar (fig. 8).—Length about 1 mm. The first-instar larva is so small that it is seldom observed. Aside from its size, it is most easily distinguished from the succeeding instars by the absence of anterior spiracles. The tracheal system in this instar opens to the exterior only at the posterior spiracles, and consists of two main

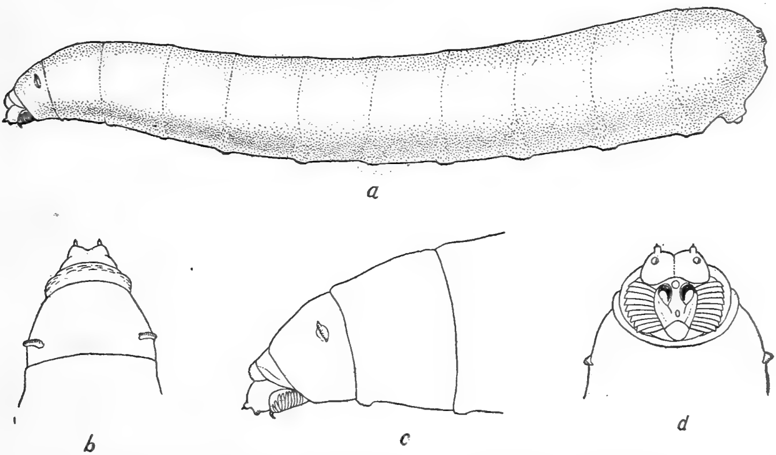

FIG. 7.—Third-instar larva of the Mediterranean fruit fly: *a*, Lateral view of entire larva; *b*, dorsal view of anterior portion; *c*, lateral view of same; *d*, ventral view. (Original.)

trunks extending the full length of the body. The posterior stigmatic plates, the outer edges of which are about 0.061 mm. apart, have two instead of three slits, as illustrated in figure 9, *a*. The mandibles or mouth hooks are not conspicuous and are of the shape indicated in figure 10, *a*.

Second larval instar.—In size the second larval instar is sufficiently large to be distinct from the first instar, but not from undersized third-instar larvæ. It may, however, be easily distinguished from the third instar by the shape of the anterior spiracles

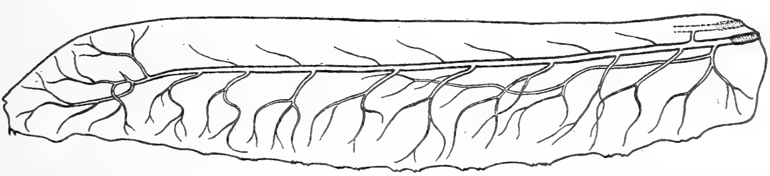

FIG. 8.—First-instar larva of the Mediterranean fruit fly, showing one of the two main tracheal systems opening at the posterior spiracles. (Original.)

(fig. 11, *a*), the mandibles (fig. 10, *b*), and posterior spiracles (fig. 9, *b*). The distance between the outer edges of the stigmal plates is about 0.13 mm.

Third larval instar.—The third-instar larva, which is about 7 to 8 mm. long, may be distinguished when well grown from the two preceding instars by its jumping habit when removed from its host, by the well-defined mandibles or mouth hooks (fig. 10, *c*), and by the prominence of the posterior spiracles. The anterior spiracles possess from 9 to 10 lobes (fig. 11, *b*) and are borne on the second segment as in the preceding stage. The posterior stigmal plates each bear three slits arranged as illustrated and are armed with four batches of delicate inconspicuous hairs (fig. 12).

The dotted lines of figure 12, indicate the general shape of the terminal chambers of the tracheal system. The body is composed of 12 distinct segments, the last of which bears the posterior stigmata upon the upper distal portion and the anus before the center of the venter in the middle of a rounded tubercle (fig. 7, *a*). The head when viewed from above or below is bilobed; each lobe bearing a distinct antennal protuberance; the dorsal and more distal one terminating in a short inconspicuous arista; the more ventral one less antennalike and without a terminal arista (fig. 7, *b*, *c*, *d*). Mouth hooks sheathed (fig. 7, *d*). Body armed only with inconspicuous spicules arranged in broken bands forming fusiform areas on the venter of the 4–12 segments; portions of the head and an irregular rind upon the anterior portion of segments 2 and 3 armed with similar spicules. There are no distinct fusiform lateral areas of spicules.

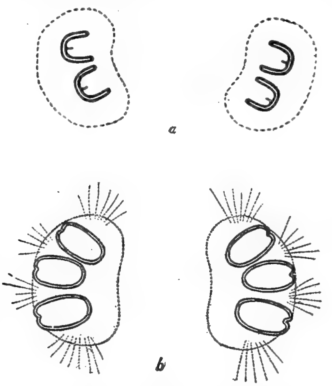

FIG. 9.—Posterior spiracles of larvæ of the Mediterranean fruit fly: *a*, First-instar larvæ; *b*, second-instar larvæ. (Original.)

DURATION OF LARVA STAGE.

The duration of the larval instars has been variously given by many writers. Martelli found that larval development at Portici, Italy, required from 9 to 10 days during summer, 11 to 12 days during early autumn, and 15 days during November and December. Severin found that larvæ matured in the winged kamani (*Terminalia catappa*) in from 8 to 17 days. Newman states that from 14 to 16 days during summer and 25 to 45 days during winter in Western Australia are the periods required for development. Other data might be given but they add nothing new to the foregoing information. No records previously published except by the writers have been accompanied by temperature data, hence they can not be satisfactorily interpreted.

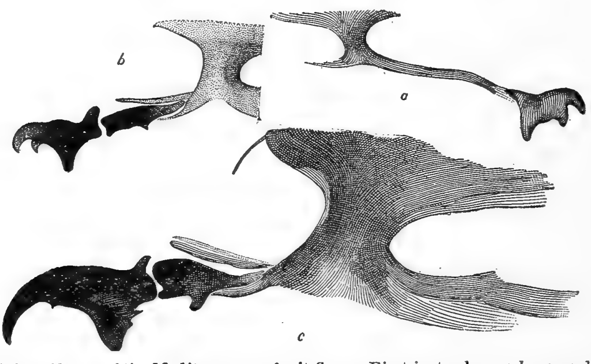

FIG. 10.—Mandibles of larva of the Mediterranean fruit fly: *a*, First-instar larva; *b*, second-instar larva; *c*, third-instar larva. (Original.)

In Honolulu larval life [1] is completed within 5.1 to 26 days. The data in Table XIV indicate the variation found in the developmental

[1] Back, E. A., and Pemberton, C. E. Life history of the Mediterranean fruit fly from the standpoint of parasite introduction. Jour. Agr. Research, v. 3, no. 5, 1915, p. 363–374.

period. During June when the mean temperature was 77.6° F. two larvæ completed their entire development in 5.1 and 5.5 days, respectively, but they were transferred daily to fresh pieces of ripe papaya and thus were surrounded by the best of conditions. However, other larvæ equally well cared for and similarly fed and transferred did not reach maturity and pupate until 6.7, 12, and 14 days. Ordinarily larvæ complete their development in from 6 to 10 days at an average mean temperature of 76° to 79° F.

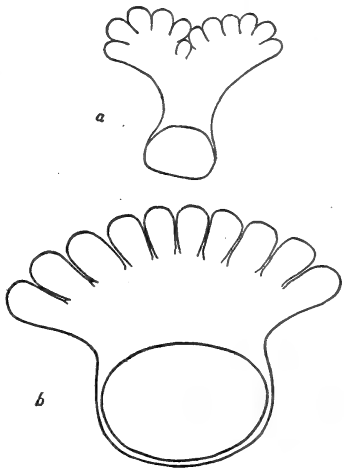

FIG. 11.—Anterior spiracles of larva of the Mediterranean fruit fly: *a*, Second-instar larva; *b*, third-instar larva. (Original.)

During the cooler part of the year, when the average mean temperature is about 69.6° F., larvæ transferred daily to fresh ripe papaya did not become fully grown until 9, 10, and 14 days old, while at about the same temperature 18, 12, and 1 larvæ required 10, 11, and 15 days for development in a green half-grown peach. At a mean temperature of about 70° to 71° F., 12, 14, 3, 1, and 1 larvæ pupated 14, 16, 19, 22, and 26 days, respectively, after hatching. Larvæ hatching during December 25 to 26 in a very firm textured apple required 19, 25, and 35 days for development when the mean temperature averaged about 68° F. Four and 3 larvæ became full grown in 6 and 7 days, respectively, in a ripe soft peach at a mean temperature of from 77° to 78° F., whereas

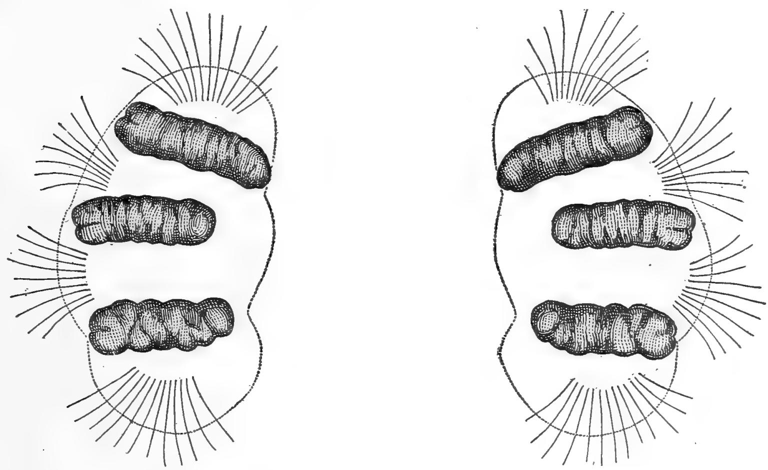

FIG. 12.—Posterior spiracles of third-instar larva of the Mediterranean fuit fly. (Original.)

under identical conditions 6 larvæ required 9.5 days in a ripe but still hard peach.

All data secured by the writers indicate that during the warmest portions of the year larval development progresses rapidly and fairly uniformly. With the approach of colder weather larval life is not only lengthened but subject to considerable and entirely unexplainable variation, even with larvæ hatching at the same time in the same fruit, especially if the host fruit happens not to be in the best condition to support larval life. The three larvæ requiring 19, 25, and 35 days for development in a very hard apple furnish a good example. In Table XV are recorded data showing the ability of cold weather greatly to increase larval life.

The data in Table XIV indicate that under favorable conditions as regards temperature and host the first larval instar is passed in from 26 to 48 hours, the second in 24 to 48 hours, and the third in 48 to 265 hours. It is profitable, therefore, to compare these and other data in Table XIV with the data of Table XV.

At an elevation of 8,250 feet, on the summit of Mauna Hualalai, Hawaii, where the temperature ranged between 27° and 73° F., but averaged for the period about 48° F., the first larval instar was found to range up to 57 days. Eighty-nine larvæ in apples were found still in the first instar after 30 days, 3 after 46 days, 7 after 54 days, and 1 after exposure for 57 days. Thirty-three larvæ in the second instar placed on Hualalai were still in this instar after 32 days, and 1 after 54 days. At Strawberry, Hawaii, a ranch station, where the temperature ranged from 39° to 79° F., 49 first-instar larvæ were found still in this instar after 27 days and 19 after 29 days. At Kealakekua, where the temperature ranged between 58° and 80° F., with a mean of about 68° F., three larvæ in apples required 28, 58, and 74 days to become fully grown and to leave the fruit to pupate.

In cold storage under what may be called artificial conditions, larval life may be variously prolonged. Thus one second-instar larva and one third-instar larva in peaches placed in storage at temperatures varying from 40° to 45° F. were found still in those instars at the end of 29 and 45 days, respectively, while check larvæ at the laboratory in the same species of host fruit completed their entire development in from 6 to 9 days. Three third-instar larvæ in apples placed in a refrigerator at temperatures varying from 48° to 52° F. were still active after 60 days and one was alive after 79 days. In a second refrigerator at temperatures ranging from 58° to 62° F., larvæ completed their development and pupated in 24, 36, 40, 44, and 50 days.

Table XIV.—*Duration of the larva stage of the Mediterranean fruit fly in Honolulu.*

Host fruit.	Number of specimens under observation.	Larva hatched.	Molted into second stage.	Molted into third stage.	Larva pupated.	Length of larva stage.	Temperature of developmental stage.	
							Range.	Mean.
							°F.	°F.
Papaya	3	Dec. 19, 9 to 10 a. m.	Dec. 21, 10 a. m. to 2 p. m.	Dec. 23, 4 p. m.	Dec. 28, 12 m.	9	61–78	69.6
Do	1	do	do	Dec. 23, 10 a. m. to 2 p. m.	Dec. 28, 4 a. m.	9	61–78	69.6
Do	2	do	do	Dec. 23, 4 to 10 p. m.	do	9	61–78	69.6
Do	1	do	do	Dec. 23, 10 a. m. to 2 p. m.	Dec. 28, 12 m.	9	61–78	69.6
Do	1	do	do	Dec. 23, 4 to 10 p. m.	Dec. 28, 10 a. m.	9	61–78	69.6
Do	1	do	do	Dec. 23, 2.45 p. m.	Dec. 28, 11 a. m.	9	61–78	69.6
Do	1	do	do	Dec. 23, 4 to 10 p. m.	do	9	61–78	69.6
Do	1	do	do	do	Dec. 28, 12 m.	9	61–78	69.6
Do	1	do	do	do	Dec. 29, 4 a. m.	10	61–78	69.6
Do	1	do	Dec. 21, 2 to 4 p. m.	Dec. 23–24, 10 p. m. to 6 a. m.	Dec. 29, 3 p. m.	10	61–78	69.6
Do	1	do	Dec. 21, 4 to 9 p. m.	do	Dec. 29, 12 m.	10	61–78	69.6
Do	1	do	Dec. 21, 10 a. m. to 2 p. m.	do	Jan. 2, 1 p. m.	14	61–79	70
Do	2	June 12, a. m.	June 14, a. m.	June 16, a. m.	June 18, a. m.	5.1	71–83	77.6
Do	3	June 12, p. m.	do	do	do	5.5	71–83	77.6
Do	1	June 19, a. m.	June 20–21, 4 p. m. to 8 a. m.	June 21–22, 4 p. m. to 8 a. m.	July 1, a. m.	12	72–83	77
Do	1	do	do	do	July 3, a. m.	14	72–83	77.1
Do	1	do	June 20, 1 to 4 p. m.	do	June 25, p. m.	6	72–83	76.4
Do	17	do	June 20–26, 4 p. m. to 8 a. m.	do	do	6	72–83	76.4
Do	2	do	do	do	June 26, a. m.	7	72–83	76.6
Green peach	2	June 22			July 2	10	72–83	77.2
Do	7	do			July 3	11	72–83	77.2
Ripe hard peach.	6	June 26			July 6	9.5	72–83	77.4
Ripe soft peach.	4	do			July 2	6	72–83	77.8
Do	3	do			July 3	7	72–83	77.7
Green peach	18	Mar. 31			Apr. 10	10	61–77	69.6
Do	12	do			Apr. 11	11	61–77	69.8
Do	1	do			Apr. 15	15	61–82	71.0
Commercial lemon.	12	Mar. 13			Mar. 27	14	57–80	70.2
Do	14	do			Mar. 29	16	57–80	70.3
Do	3	do			Apr. 1	19	57–80	70.5
Do	1	do			Apr. 4	22	57–80	70.4
Do	1	do			Apr. 8	26	57–80	70.4
Apple	1	Dec. 25, 1914			Jan. 13, 1915	19	67–81	71.6
Do	1	do			Jan. 19, 1915	25	67–81	71.1
Do	1	Dec. 26, 1914			Jan. 30, 1915	35	67–81	70

The data recorded in Table XV only indicate the possibilities in lengthening larval life. Except at temperatures from 58° to 62° F., none of the larvæ would have been able to mature had they been kept at the temperatures recorded. The data merely bring out the fact that upon the examination of the host fruits after so many days the larvæ recorded were found alive. A very large percentage of the larvæ within the same fruits were dead, but this mortality, due to exposure to cold for prolonged periods, is discussed elsewhere.

TABLE XV.—*Showing ability of low temperatures to lengthen larval life of the Mediterranean fruit fly.*[1]

Number of specimens under observation.	Instar.	Locality.	Temperature. Range.	Temperature. Mean.	Length of instar or instars.
			°*F.*	°*F.*	*Days.*
1	2	Cold storage	33–38		15
2	3	Cold storage	33–38		17
1	2	Cold storage	40–45		29
1	3	Cold storage	40–45		45
12	3	Refrigerator No. 1	48–54	50	24
1	3	Refrigerator No. 1	48–54	50	36
3	3	Refrigerator No. 1	48–54	50	60
1	3	Refrigerator No. 1	48–54	50	79
1	1,2,3	Refrigerator No. 3	58–62	60	24
1	1,2,3	Refrigerator No. 3	58–62	60	36
1	1,2,3	Refrigerator No. 3	58–62	60	40
1	1,2,3	Refrigerator No. 3	58–62	60	44
3	1,2,3	Refrigerator No. 3	58–62	60	50
1	1,2,3	Kealakekua	58–80	69	28
1	1,2,3	Kealakekua	58–80	69	58
1	1,2,3	Kealakekua	58–80	69	74
41	1	Hualalai	27–73	48	12
1	1	Hualalai	27–73	48	26
89	1	Hualalai	27–73	48	30
1	1	Hualalai	27–73	48	45
3	1	Hualalai	27–73	48	46
7	1	Hualalai	27–73	48	54
1	1	Hualalai	27–73	48	57
33	2	Hualalai	27–73	48	32
1	2	Hualalai	27–73	48	54
133	1	Puulehua			54
1	1	Puulehua			17
14	1	Puulehua			36
49	1	Strawberry	39–79		27
19	1	Strawberry	39–79		29

[1] In securing these data apples were used as host fruits in all but the first four records for cold storage, for which peaches were used.

In spite of the ability of cold temperatures to prolong larval life greatly beyond the usual period required for development during warm Hawaiian weather, it is interesting to record that individual larvæ whose development has been slowed down, or even practically suspended, will continue their development normally when returned to warmer temperatures. Thus one second-instar larva which had been held for 54 days on Hualalai on being taken to Kealakekua on March 26, where the mean temperature was about 66.8° F., and then to Honolulu on March 29, molted into the third instar on March 30. A second larva placed on Hualalai just after hatching and kept there until March 17, or 45 days, on being taken to Kealakekua molted into the second instar on March 21, into the third instar on March 24, pupated March 28, was taken to Honolulu on March 29, and emerged as an adult on April 10.

PUPA.

DESCRIPTION OF PUPARIUM.

Puparium (Fig. 13, *a*, *b*, *c*).—Puparium elliptical in general shape; a little more convex on the dorsal side; length about 4 to 4.5 mm. The size and color of puparium vary and depend upon the amount and nature of larval food. Puparia formed by larvæ feeding on coffee cherries dull white; the usual color light or dark testaceous. There are only 11 distinct segments, the first being composed of the first and second larval

segments, and therefore bearing indications of the mouth opening and anterior spiracles of latter; last segment likewise bearing the remains of anal and stigmatal openings of larva

DURATION OF PUPA STAGE.

Mally has found in South Africa, at Grahamstown, that the duration of the pupa stage may be as long as 35 days in a rearing box kept "at the ordinary seasonal temperature." Martelli states that in southern Italy the pupa stage varies with the progress of the season; that it may be from 10 to 11 days during summer (August), 18 to 20 days during autumn (October), or 30 or more days during the winter. Newman found in Western Australia the periods to be from 12 to 14 days during summer and 25 to 50 days during winter. Nearly all writers have offered data on the duration of this stage, but, unaccompanied by temperature or humidity records as they are, they add nothing new to the foregoing information.

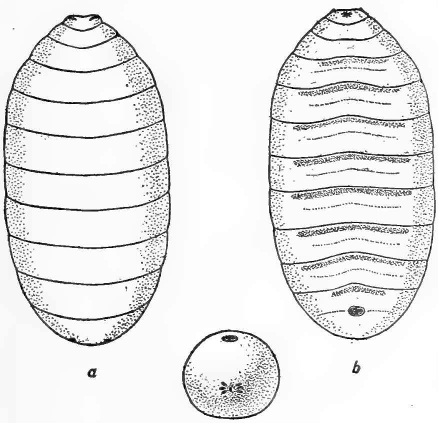

FIG. 13.—Pupa of the Mediterranean fruit fly: *a*, Dorsal view; *b*, ventral view; *c*, posterior end, showing anal scar and spiracles. (Original.)

In a previous paper the writers give data, accompanied by temperature records, on observations including about 2,000 pupæ developing under Honolulu conditions. From these it would appear that the minimum length of pupal life is about 6 days when the mean temperatures range between about 76° and 79° F. During the warmest Honolulu weather the largest proportion of any lot of pupæ require from 9 to 11 days before yielding adults. Thus at a mean of about 76° F. 5, 14, 101, 160, 7, and 3 pupæ yielded adults 6, 9, 10, 11, 12, and 13 days, respectively, after the formation of the puparium.

The pupa stage may be increased to at least 19 days when the daily means drop to about 69° to 71° F. The data in Table XVI covering observations on 7,000 pupæ are given in corroboration of this statement. At a mean temperature of about 66.8° F., pupæ required from 20 to 28 days to complete their development at Kealakekua, Kona, Hawaii. In Table XVI are given a large number of records covering the coldest portions of the year in the usual fruit-growing sections of the islands. These records, together with many others on file, given in Table XXV in connection with parasite work, indicate that there occurs no dormancy among pupæ at these temperatures. In other words, while development is considerably retarded, there is no yielding of adults by a few pupæ while others

yield adults after a period of dormancy for several months as has been found to be true of the parasites *Diachasma tryoni* and *Diachasma fullawayi*.

TABLE XVI.—*Duration of the pupa stage of the Mediterranean fruit fly in Hawaii (7,000 pupæ).*

Date of pupation.	Date of emergence.	Number adults emerging.	Length pupa stage.	Mean temperature.	Date of pupation.	Date of emergence.	Number adults emerging.	Length pupa stage.	Mean temperature.
			Days.	*° F.*				*Days.*	*° F.*
Feb. 3[1]	Feb. 23	9	20	66.8	Dec. 18–20	Jan. 1	167	12–14	72.9
Do.....	Feb. 24	3	21	66.8	Do.....	Jan. 2	466	13–15	72.8
Do.....	Feb. 25	82	22	66.8	Do.....	Jan. 3	152	14–16	72.7
Do.....	Feb. 26	69	23	66.8	Do.....	Jan. 4	3	15–17	72.5
Do.....	Feb. 27	1	24	66.8	Do.....	Jan. 5	2	16–18	72.4
Do.....	Mar. 3	1	28	66.8	Do.....	Jan. 6	1	17–19	72.3
Feb. 27[2]	Mar. 13	7	14	70.4	Dec. 22–29	Jan. 4	27	11–13	72.4
Do.....	Mar. 14	40	15	70.3	Do.....	Jan. 5	528	12–14	72.3
Do.....	Mar. 15	15	16	70.4	Do.....	Jan. 6	541	13–15	72.1
Do.....	Mar. 17	17	18	70.9	Do.....	Jan. 7	804	14–15	71.9
Do.....	Mar. 18	3	19	70.9	Do.....	Jan. 8	57	15–17	71.5
Dec. 1	Dec. 12	8	11	73.2	Do.....	Jan. 10	1	17–19	71.3
Do.....	Dec. 13	279	12	73.1	June 10	June 16	5	6	76.4
Do.....	Dec. 14	269	13	73.1	Do.....	June 19	14	9	76.3
Do.....	Dec. 15	116	14	73.2	Do.....	June 20	101	10	76.3
Do.....	Dec. 16	29	15	73.4	Do.....	June 21	160	11	76.2
Dec. 8–10	Dec. 19	2	9–11	73	Do.....	June 22	7	12	76.1
Do.....	Dec. 20	1	10–12	73	Do.....	June 23	3	13	76.3
Do.....	Dec. 21	98	11–13	73.1	July 13	July 20	1	7	79.2
Do.....	Dec. 22	478	12–14	73.2	Do.....	July 21	3	8	79.2
Do.....	Dec. 23	189	13–15	73.2	Do.....	July 22	39	9	79.2
Do.....	Dec. 24	2	14–16	73.2	Do.....	July 23	43	10	79.1
Dec. 16–18	Dec. 27	24	9–11	73.3	Do.....	July 24	3	11	79
Do.....	Dec. 28	96	10–12	73.1	June 8	July 16	2	8	76.2
Do.....	Dec. 29	654	11–13	73.2	Do.....	July 17	15	9	76.2
Do.....	Dec. 30	712	12–14	73.2	Do.....	July 18	28	10	76.1
Do.....	Dec. 31	72	13–15	73.2	Do.....	July 19	53	11	76.1
Dec. 18–20	Dec. 29	4	9–11	73.2	Do.....	July 20	53	12	76.1
Do.....	Dec. 30	41	10–12	73.1	Do.....	July 21	5	13	76.1
Do.....	Dec. 31	415	11–13	73					

[1] At Kealakekua, Kona, Hawaii. [2] At Honolulu.

While it is probable that the duration of the pupa stage in any fruit-growing section in Hawaii is never more than 20 to 28 days (average mean temperature 66.8° F.) the writers have shown that it may be much longer under cooler conditions. As a contribution toward what the maximum duration may be, the following data are presented.

In a glass refrigerator of the usual type for displaying fruits and vegetables, which was kept at a temperature of from 58 to 62° F., the duration of pupal life was found to range between 23 and 38 days when the pupæ were placed within storage within half a day after the formation of the puparium. Thus 4, 12, 9, 16, 44, 367, 1,217, 159, 25, 11, 5, 1, and 1 adults emerged in the refrigerator after 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, and 38 days, respectively, of refrigeration. One pupa 8 days old was held in storage at from 40 to 45° F. for 27 days and yielded an adult 2 days after removal to normal temperature, or 37 days after pupation. One hundred pupæ placed in a refrigerator when one-half day old and held continuously at a temperature of from 54 to 57° F. for 24 days, on removal to normal temperatures produced 2, 27, and 5 adults in 4, 5, and 6 days, respectively, after removal, or 28, 29, and 30 days after pupation. A second lot of 100 pupæ, placed at 54 to 57° F. when 1 day old, produced 3, 16, 9, 3, 2, 4, and 2 adults in refrigeration in 31, 32, 33, 34, 35, 36, 37, and 38 days, respectively, after pupation.

Pupæ formed by larvæ pupating within a refrigerator held at 52 to 56° F. yielded 2 and 1 adults within storage after refrigeration for 38 and 52 days, respectively. Out of 39,500 pupæ held in like manner at from 49 to 51° F. only 1, 2, 2, 3, and 1 pupæ yielded adults in storage after 20, 23, 44, 46, and 47 days, respectively, of refrigeration. These 9 pupæ yielding adults were 5 days old when placed in cool storage; hence they were 25, 28, 49, 51, and 52 days old when they yielded adults. One 3-day-old pupa held at an even temperature of 32° F. for 9 days, on removal to normal temperature produced an adult on November 14, 10 days later, or when 23 days old. Two 1-day-old pupæ refrigerated for 19 days and then removed to normal temperatures yielded adults in 29 and 30 days, respectively, after pupation. Investigators working in countries where the temperature falls for short periods to or slightly below freezing are referred for other data to a previous paper by the writers [1] in which are given data on the effects of 32°, 33° to 34°, 33° to 36°, 28° to 40°, 38° to 40°, 40° to 45°, 49° to 51°, 52° to 56°, and 54° to 57° F. upon 173,318 pupæ.

During January–March, 1915, the writers secured data on the effect upon the duration of pupal life of out-of-door temperatures at elevations of about 3,700 feet at Strawberry, at 5,000 feet at Puulehua, and on Mauna Hualalai at 8,250 feet. Pupæ formed at Honolulu on January 31, shipped to Kealakekua on February 9–10, and placed at Strawberry on February 11, were found to have produced 1, 72, 392, 4, and 6 adults on February 24, 25, 27, and March 3. The temperature at Strawberry for these periods ranged from 42 to 69° F. with a mean of about 56° F. Other pupæ formed at Honolulu on February 8, shipped to Kealakekua February 9–10, and placed at Strawberry February 11, were found to have yielded 3, 307, 503, and 13 adults on March 11, 17, 20, and 25, respectively. Pupæ formed at Honolulu on February 6, shipped to Kealakekua February 9–10, placed at Puulekua February 11, where the temperature between February 11 and March 26 ranged from 38° F. to 72° F., with a mean of 53° to 54° F., were found to have yielded 2, 10, 108, 126, and 13 adults on March 9, 17, 20, 25, and 26, respectively. The pupæ yielding adults on March 26 were 48 days old. Other pupæ formed at Kealakekua on January 26 and taken the same day to Puulehua yielded no adults before March 25, when they were removed to Kealakekua, where the temperature ranged during March 24–27 between 60 and 84° F. At Kealakekua 2 and 16 pupæ yielded adults on March 26 and 27, respectively, *or when 59 and 60 days old.* Pupæ formed at Honolulu February 12, shipped to Kealakekua February 17, and placed at Puulehua February 24, were found to have yielded 4, 96, and 1 adults on March 9, 17, and 20, respectively. Pupæ formed at Kealakekua January 27, taken to Hualalai January 31, and removed to Kealakekua March 26, produced no adults, and on examination appeared not to have been able actually to pupate. The temperature on Hualalai for the period ranged between 31° and 70° F. Pupæ formed at Honolulu February 9, placed on Hualalai February 12, and removed to Kealakekua March 2, yielded 10 adults between March 17 and 20, or when 36 to 39 days of age. Pupæ formed at Honolulu February 5 and taken to Hualalai February 11 were found to have yielded 51 adults between March 23 and 26. On March 26 they were removed to Kealakekua, where 17 and 2 yielded adults on March 27 and 28, respectively, or 50 and 51 days after pupation. Of this lot of pupæ, 1,820 did not survive the Hualalai temperature. Pupæ formed at Honolulu February 7, placed on Hualalai February 12, and removed to Kealakekua March 26, yielded 52 adults on March 31, or 52 days after pupation, but 1,506 failed to survive.

The data presented are of particular interest in bringing out the ability of pupæ to survive various climatic conditions apt to be experienced in countries harboring fruit flies. It will be noted that 60 days is the longest period obtained by the writers for pupal development.

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[1] Back, E. A., and Pemberton, C. E. Effect of cold-storage temperatures upon the pupae of the Mediterranean fruit fly. Jour. Agr. Research, v. 6, no. 7, 1916, p. 251–260.

THE ADULT.

DESCRIPTION.

A general idea of the relative size and coloration of the adult of the Mediterranean fruit fly may be gained by an examination of text figures 1 and 14, and Plate I figure 1, and Plate VIII figure 3. The adults vary from 3.5 to 5 mm. in length. The description by Froggatt is as follows:

Size 4 to 5 mm. about the size of an average house-fly, but looking somewhat smaller when dead, because the body shrinks up beneath the thorax. General color, ocherous yellow, lighter on the sides of thorax and basal joints of the antennae. The eyes of the usual reddish purple tint, with a blackish blotch in the center of the forehead, from which spring two stout black bristles, a fine fringe of similar bristles round the

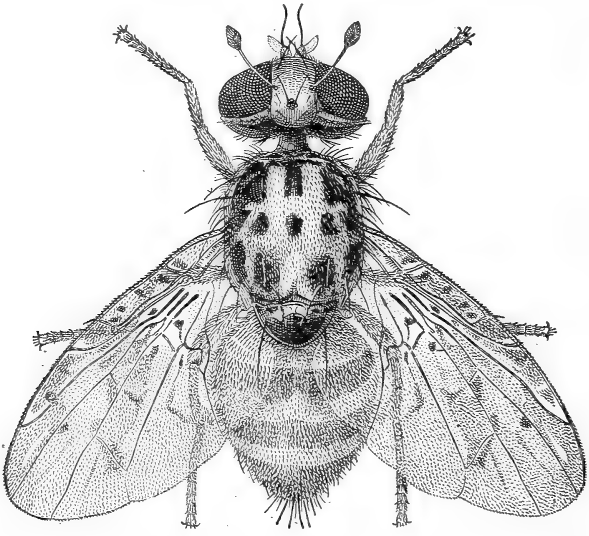

FIG. 14.—The Mediterranean fruit fly (*Ceratitis capitata*): Adult male. Greatly enlarged. (Original.)

hind margin of the head, with some coarser ones curving round in front of the head between the eyes. The thickened basal joints of the antennae pale yellow, the terminal segments black to the tips. The dorsal surface of the thorax convex, raised, and broadly rounded with the scutellum, the ground color creamy white to yellow, marbled with shiny black blotches forming an irregular mosaic pattern, the lighter portions clothed with very fine white bristles. These light-colored bristles more lightly scattered over the dark areas, and the whole bearing large stout black bristles thickest on the black surface. In many of the pictures of this insect the black areas are drawn as if they were projecting bosses or knobs, but this is incorrect; the whole forms a regular rounded surface.

The wings are broad, semiopaque, with the extreme base blotched with ocherous or brownish yellow, with the rest of the basal area curiously marked with black, forming dark lines of the radiating nervures, with dark lines and spots between; beyond this is a broad irregular transverse ocherous band, slightly lined with black, blotched at the extremity; another similar shaped and colored blotch runs along inside but

not in contact with the costal nervure, also blotched towards the extremity in the angular space. Between these bands is another shorter black band running parallel with the first transverse band.

The oval abdomen is clothed on the upper surface with fine, scattered black bristles, and has two rather broad transverse silvery white bands on the basal half of the body. The male differs from the female in being furnished with a pair of stalked appendages standing out in front of the head in a line with the front margin of the eyes, the extremities of which filaments are produced in spatulate appendages, black, finely striated, and diamond shaped.

The living fly is an active little creature, running about over the foliage or fruit on the trees, with its wings drooping down on the sides of the body. When disturbed it has a short flight, seldom flying more than a few yards at the most, and it often returns to the same spot.

EMERGENCE.

The adults of the Mediterranean fruit fly emerge in largest numbers early in the morning during the warmer portions of the Hawaiian year, but more scatteringly during the cooler portions. During the summer the larger proportion of adults emerge between 5 and 8 a. m. On December 31, 1914, when the temperature ranged from 66° to 78° F. and the mean relative humidity was 72 per cent, 55, 58, 125, and 16 adults emerged between the hours 6 to 8 a. m., 8 to 10 a. m., 10 a. m. to 1 p. m., and 1 to 4 p. m., respectively. On January 2, 1915, when the temperature ranged from 68° to 76° F. and the relative humidity was 58 per cent, 141, 159, 28, and 12 adults emerged between the hours 6 and 8 a. m., 8 and 10 a. m., 10 a. m. and 12 m., and 12 m. and 2 p. m., respectively.

The adult when issuing from the puparium seems invariably to cause a fairly regular split from the cephalic tip of the puparium straight back along each side to near the middle of the fourth segment and then upward over the dorsum, following a line fairly well in the center of the fourth segment, and often splitting entirely around the center of this segment. Thus the upper half of the first three segments and the upper anterior half of the fourth segment of the puparium are usually broken away by the pressure of the ptilinum, and often the entire anterior portion of the puparium is broken off back to the middle of the fourth segment during the emergence of the adult.

Once out of the puparium, the adult forces its way to the surface of the soil or out of other confinement, with the aid of the ptilinum. Before the natural coloration appears and while the chitin of the body is still pliable, the adults are able to force their way through incredibly small openings or cracks, through loose cotton stoppers, and sometimes beneath rubber bands. Often the united efforts of a few adults will force an exit in places from which single adults unaided could not escape.

DURATION OF ADULT LIFE.

WITHOUT FOOD.

If adults have no opportunity to feed after emergence they die within 4 days. Ninety adults issuing on March 15 and kept under starvation conditions were all dead by the end of the third day. On the second and third days, 68 and 22 adults, respectively, died, and at 9 a. m. on the third day only 4 were barely alive, and these were dead by 5 p. m. Of 50 adults emerging on March 14, 1, 48, and 1 died on 1, 3, and 4 days later. French states that he found that adults died in Australia within 4 days if kept without food. The writers have handled many thousands of adults during the past 3 years and have never had flies live longer.

If given only water, life is slightly prolonged. Of 300 adults emerging on October 17, 250 had died by the end of the second day, while the remaining 50 were dead by the end of the third day. Of 42 adults emerging May 20, 12, 25, 4, and 1 died after 2, 3, 4, and 5 days.

WITH FOOD.

In 1899, Lounsbury in South Africa confined adult flies in a wire cage out of doors to determine the length of adult life. By the use of apples as food, 1 female out of an original number of 60 was kept alive from March 30 to July 19, or about 16 weeks. French states that adults live to be 25 days old during March in Victoria, Australia. Gurney found that in confinement adults live from a few days to three weeks. Newman states that he has found that flies live usually 6 weeks, but when no suitable food is available for oviposition, they may live from 8 to 10 weeks. Later the same writer gives the length of adult life in western Australia as ranging from 28 to 40 days in summer and from 28 to 65 days in winter.

The writers have found that even when given the best of care many adults die very young. In every lot confined in jars about 50 per cent may be expected to die during the first 2 months. The early death of many flies does not seem to be caused always by overcrowding, for frequently single adults given the best of care in separate jars die at all ages from 1 to 2 days on. The greatest interest in connection with the longevity of adults must center in the minority that live for long periods.

In a preliminary paper the writers record 1 adult that lived from December 31, 1913, to May 11, 1914, or 131 days, and others emerging on February 28, 1914, that were still alive on August 1, or 5 months after emergence. Additional data have since been secured. One female emerging on the same date died on September 4, or at the age of 5 months; another female emerging on the same date died on September 30. About 500 adults emerging on June 28 were placed in large glass jars; on August 14 only 40 were still living. The last two of these 40 adults died on October 2, at the age of 97 days. The

rate of mortality for the 40 is as follows: On August 14, 28; September 4, 9, 12, 15, 17, 19, 21, 23, 24, and October 2 and 3, there were alive 40, 30, 17, 12, 11, 10, 10, 7, 5, 4, 2, 2, 0 adults. Two hundred and twenty-five adults which emerged on December 31, 1913, were placed in a large glass jar and fed daily. The last fly which died lived to be 131 days old. A general idea of the mortality of these flies may be had from the fact that when examinations were made on March 9, 13, 18, 22, 26, 31, April 1, 6, 13, 15, 17, 18, 19, 26, 27, 28, 30, May 1, 3, 5, 7, 9, 10, and 11, there were living 225, 214, 202, 171, 139, 94, 59, 47, 36, 32, 28, 25, 18, 16, 13, 12, 11, 9, 7, 5, 4, 3, 2, and 1, respectively.

One female emerging on February 28, 1914, died on August 3; two males emerging on the same date died on October 5 (7 months, 5 days), and on October 15 (7 months, 15 days), respectively. One female emerging on March 3, 1914, died on September 8 (6 months, 3 days). The death rate among 95 males and 58 females, the only survivors on July 3 of a lot of 800 adults emerging on February 28, 1914, is given in Table XVII. The oldest fly lived 230 days, or 7 months and 10 days.

TABLE XVII.—*Data on longevity of adults of the Mediterranean fruit fly emerging on Feb. 28, 1914, which had survived until July 3.*

Date.	Adults still alive.		Date.	Adults still alive.		Date.	Adults still alive.	
	Male.	Female.		Male.	Female.		Male.	Female.
July 3	95	58	Aug. 15	19	2	Sept. 11	5	0
July 9	80	38	Aug. 18	14	2	Sept. 12	3	0
July 13	58	25	Aug. 22	11	2	Sept. 18	2	0
July 18	48	20	Aug. 25	10	2	Oct. 5	1	0
July 25	41	12	Aug. 29	9	2	Oct. 16	1	0
Aug. 1	35	6	Sept. 1	8	2	Oct. 17	0	0
Aug. 8	26	3	Sept. 8	6	0			

One female, emerging May 22, 1914, and kept continuously in a well-lighted glass refrigerator at 58°–62° F., lived until April 1, 1915, 315 days, or 10 months and 10 days. The rate of mortality of the flies still living of this lot on December 4 is recorded in Table XVIII.

TABLE XVIII.—*Data on longevity of adults of the Mediterranean fruit fly emerging on May 22, 1914, and kept in a glass refrigerator at 58°–62° F.*

Date.	Adults still alive.		Date.	Adults still alive.		Date.	Adults still alive.	
	Male.	Female.		Male.	Female.		Male.	Female.
Dec. 4	43	62	Jan. 5	17	32	Feb. 4	4	10
Dec. 15	31	55	Jan. 8	16	30	Feb. 10	1	6
Dec. 19	26	51	Jan. 13	14	28	Feb. 13	1	4
Dec. 23	24	48	Jan. 18	14	24	Feb. 17	1	3
Dec. 26	24	43	Jan. 26	9	20	Mar. 6	0	2
Dec. 29	24	37	Jan. 29	7	16	Apr. 1	0	1
Jan. 2	21	36	Feb. 1	4	12	Apr. 2	0	0

Of the adults kept at 58–62° F. the majority died after the sixth month of life, being caught by the wings in moisture gathering on the sides of the containing jars. Under more favorable conditions the writers believe that adult life may be extended to cover a full year.

MATING.

Martelli first described the mating process. He says that when the male desires to copulate he "seeks to attract the female by curving up and raising the last abdominal segment, then bending the extremity, swelling it to the form of a pinhead, while the venter is drawn back half its length and the abdomen is puffed out laterally, etc." These evidences of sexual stimulation have been verified by the writers. In addition to the dorso-ventral contraction and lateral expansion of the abdomen, the male may vibrate his wings rapidly for periods of 10 to 15 seconds, at the same time that he extrudes the rectum (?) to form the white bulbous structure which is held almost perpendicularly over the tip of the abdomen.

Often the female will move toward the head of the male from the opposite direction to be greeted when within an inch of the male by a violent fanning of the wings of the latter. When the female is within half an inch of the male, the male moves forward in a halting fashion until the heads of each almost touch, when the male springs forward and endeavors to clasp the female, but is often repulsed. One pair were observed to go through this process five times in 30 minutes before copulation occurred. Having once placed himself, the male makes vigorous efforts to bring the tip of his abdomen in contact with the tip of the ovipositor, trying at the same time to grasp the very tip of the ovipositor with the strong chitinized claspers situated on the seventh sternite. The female need only extend the tip of the ovipositor to but a very slight degree from within the last abdominal segment and the male will quickly clasp it and draw it out to a considerable length. The operation of clasping the ovipositor and drawing it out usually takes from 10 to 20 seconds. At the end of 15 to 20 seconds, or even sooner, the long narrow ribbonlike chitinized copulatory organ begins slowly to uncoil from its position. It extends up over either the left or right side of the sixth and seventh abdominal segments and makes one, or sometimes two, loops about the distal fourth with the tip resting under the posterior edge of the fifth tergite. From this position the penis uncoils until the tip comes to a position almost between the claspers, where it enters the vaginal opening.

Both males and females mate frequently throughout life. One male was observed mating between 3 and 4 p. m., February 3, 1915, and between 11 a. m. and 12 m. and 1 and 3 p. m., February 4. Males observed mating on February 4, 1914, mated again on February 5, 6, 7, and 8. Individual females kept for oviposition records have been observed to mate frequently with the males accompanying them. Such data indicate that mating is frequent. Such frequent mating is, however, unnecessary for egg fertility, inasmuch as one female emerging August 12 and observed mating September 8 (probably not for the first time) was isolated on that date and placed with fruit. She deposited 139 eggs between September 16 and November 25, and all

hatched normally. Records on file show that the eggs deposited by 12 other females isolated after mating on September 8 hatched normally.

SEXUAL SMELL.

The writers have found that the males of the Mediterranean fruit fly emit a peculiar odor by which they may be recognized. A segregation of the sexes proved that the females do not emit this odor, or at least that no odor can be detected. That given off by the males is very evident and, while difficult of description, resembles somewhat that of stale mucus. No odor can be detected until the males begin courting the females, but from that time on it is sufficiently strong so that during calm weather a person sitting as far as 4 feet from jars containing adults is able to state whether the flies within are *Ceratitis capitata* or *Bactrocera cucurbitae*. The latter species emits no odor. The writers have attempted to make use of the odor emitted by the males to trap the females in the laboratory and field, but in no instance were females attracted to jars containing males, although the odor eminating from the latter was pronounced. Males kept at 58° to 62° F. neither courted the females nor gave off their characteristic odor.

AGE AT WHICH MATING AND OVIPOSITION BEGIN.

Adults, upon emerging from the pupa, must feed for several days before they show evidences of sexual activities or begin oviposition. Berlese, in Italy in 1905, published the first data bearing on this subject. He states that the female does not oviposit until 10 to 12 days after emergence. Severin states that in Honolulu no fully developed eggs were present in the ovaries of 3 females 8 days after emergence. Although from the eighth day on he made daily dissections of 3 females, he found no mature eggs until the fourteenth day, with the exception of a few in the ovaries of a single female 11 days after emergence. The most careful observations appear to have been made by Martelli, who states that females do not oviposit until from 4 to 7 days after emergence during summer, or 10 to 12 days during the autumn. Aside from Martelli's general reference to the season, no writer has published along with his statements data on temperatures, which the writers have found to be an important factor.

The age at which the first eggs are deposited varies with the temperature. During late July and early August, 1913, when the daily temperatures at Honolulu ranged between 74° and 86° F., with a mean for the period of 79° to 80° F., males began to show sexual activity within 3 days, while mating and egg laying took place within 4 to 5 days. In securing infestation of fruits it was found that while few eggs were deposited within 4 to 5 days after emergence, it was not until 7 to 10 days after emergence that any lot of females seemed to reach their full egg-laying capacity. These observations are based

on work with over 20,000 adults. During the period May 21 to 28, 1913, when the daily temperatures ranged between 69° and 82° F., with a mean temperature for the period of 76° F., and with a mean relative humidity about 66 per cent, many females were not observed mating until 7 to 9 days.

During the period December 14 to 24, 1914, when the weather was unusually cool for Honolulu, with the daily temperatures ranging between 61° and 78° F. (a mean for the period about 69.8° F.), and the mean relative humidity about 72 per cent, 1 male was observed giving the usual evidences of sexual maturity 8 days after emergence, and several others after 9 days. The first eggs, 3 in number, from about 150 females were obtained 8 days after emergence, while 10 and 38 eggs, respectively, were secured after 9 and 10 days. Adults emerging on January 3, 1916, did not contain well-developed eggs until 10 days later, as shown by daily dissections. The temperature during this period ranged between 60° and 75° F., with a mean of 68.7° F. The general process of egg formation as it takes place in the egg tubes is shown in figures 15 and 16, representing the development of the eggs 1, 3, 8, and 10 days after emergence.

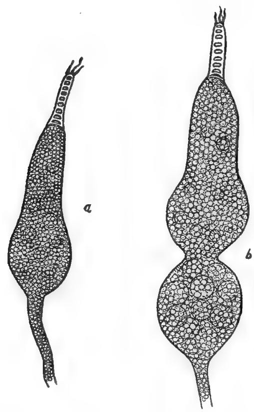

FIG. 15.—Egg tubes of female Mediterranean fruit fly: *a*, At time of emergence; *b*, 3–5 days after emergence; during January, 1916. (Original.)

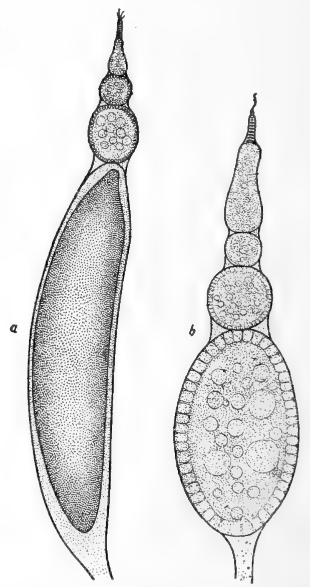

FIG. 16.—Egg tubes of female Mediterranean fruit fly: *a*, Development after 10 days; *b*, after 8 days; during January, 1916, at Honolulu. (Original.)

PORTIONS OF PLANT SELECTED.

Adults of the Mediterranean fruit fly oviposit only in the fruit of the host. The female appears to have no preference for any particular area in the epidermis of very soft fruits, such as the strawberry guava, mock orange, coffee, peach, sapota, or eugenia, as egg punctures are to be found on all portions of the fruit. But even in these fruits adults oviposit most freely in prematurely ripened areas. In the case of other fruits, the epidermis of which the fly has greater difficulty in puncturing, females are apt to take advantage of previously made abrasions caused by thorn pricks, fungus attack, old egg punctures, etc. Thus the females often deposit eggs in large numbers

only in a single break made by the mango weevil or fungus attack on the skin of a large choice Indian mango. In cotton bolls eggs appear to be deposited only in breaks made by the larvæ of the pink bollworm (*Pectinophora gossypiella* Saund.). In some varieties of avocados eggs are most often deposited, in certain localities, in the cracks made by fungi, although other varieties with thinner skins are freely oviposited in at all points.

DAILY RATE OF OVIPOSITION.

No data on the daily rate of oviposition have ever been published except by the writers. In a preliminary paper they record the daily rate of oviposition during the first 18 weeks after emergence. In Table XIX these data have been continued to include the oviposition records of the same females throughout life. For the daily rate of oviposition for old females see Table XX. It will be noted that there is considerable variation in the frequency of oviposition among those specimens seemingly less hardy, but that those living longest, and apparently the most normal, oviposited with great regularity a few eggs nearly every day. The 9 females, the oviposition records of which appear in Table XIX, emerged on April 4, 1914, and were placed with fruit April 14.

The best record in Table XIX is that of fly No. 5, which oviposited with great regularity from April 16 to September 2. During life this fly oviposited on 106 days of 153. Of the 47 days on which she laid no eggs, 20 were the first 20 days of her life and 13 of these 20 were evidently consumed in reaching sexual maturity. Hence, after she began ovipositing with regularity she failed to oviposit on only 27 of 133 days. Fly No. 8, which lived 147 days, oviposited on 80 days. Fly No. 9, which lived 65 days, deposited only 3 eggs on May 4 and 5. Had it been possible to secure oviposition data on many individuals it is probable that the record of fly No. 5 would have been exceeded and that many gradations would have been secured between the records of flies Nos. 5 and 9. This is probable, inasmuch as other females recorded under the subject of longevity lived to be over 10 months old, and there is no evidence that oviposition necessarily ceases before death. It is not likely, however, that the actual number of eggs deposited on individual days would have been found greater than those recorded in Table XIX. This actual number of eggs deposited on individual days was found to vary from 1 to 22. The average numbers of eggs deposited by the 9 females, taking into consideration only the days on which oviposition occurred, are 6.6, 3.1, 5.7, 7.5, 5.9, 6.1, 5.9, 5.2, and 1.5. Flies Nos. 5 and 8, which lived the longest, deposited, respectively, an average of 5.9 and 5.2 eggs.

TABLE XIX.—*Daily rate of oviposition of the Mediterranean fruit fly in 1914.*

[Females emerged on Apr. 4, 1914, and were placed with fruit on Apr. 14, 1914.]

Date of oviposition.[1]	Number of eggs deposited.								
	Fly No. 1.	Fly No. 2.	Fly No. 3.	Fly No. 4.	Fly No. 5.	Fly No. 6.	Fly No. 7.	Fly No. 8.	Fly No. 9.
Apr. 16	3	0	0	0	0	0	0	0	0
17 to 20	14	7	11	24	19	14	0	0	0
20 to 22	0	0	0	0	0	0	5	0	0
22 to 24	0	0	7	0	0	0	0	2	0
25 to 26	0	7	13	0	13	0	14	0	0
27 to 28	11	8	6	0	16	15	0	20	0
29 to 30	0	0	0	0	17	16	23	0	0
May 1 to 3	0	0	0	3	25	19	19	13	0
4 to 5	25	0	0	0	12	0	0	0	3
6	2	0	0	0	0	0	9	0	0
7	8	0	0	0	19	12	2	8	0
8	9	0	0	0	9	3	1	0	0
9	9	0	0	0	7	7	4	3	0
10	0	0	0	2	0	6	2	0	0
11	17	0	0	0	7	3	0	0	0
12	4	4	0	0	10	4	8	0	0
13	14	0	0	0	7	8	11	0	0
14	8	4	0	0	10	2	9	0	0
15	8	0	0	5	5	6	6	1	0
16	5	0	0	0	11	6	8	14	0
17	8	0	0	0	0	4	3	0	0
18	2	0	0	13	3	3	3	8	0
19	3	4	0	0	5	0	3	9	0
20	2	(2)	0	0	6	9	3	11	0
21	0	......	0	0	2	2	9	8	0
22	5	......	0	0	5	0	1	9	0
23	10	......	20	4	6	10	4	4	0
24	4	......	2	18	3	1	4	7	0
25	5	......	19	4	2	3	3	3	0
26	0	......	2	9	6	2	0	3	0
27	0	......	6	15	9	0	5	8	0
28	0	......	(3)	3	3	5	3	4	0
29	9	......	......	9	3	14	7	7	0
30	1	......	......	12	0	8	10	4	0
31	0	......	......	9	6	13	21	8	0
June 1	0	......	......	8	3	10	5	5	0
2	0	......	......	13	5	6	14	6	0
3	0	......	......	9	12	4	7	2	0
4	5	......	......	3	3	4	3	9	0
5	0	......	......	7	8	0	6	5	0
6	0	......	......	4	6	0	4	3	0
7	0	......	......	18	11	15	15	12	0
8	0	......	......	0	0	1	0	1	0
9	0	......	......	15	7	8	12	9	0
10	0	......	......	6	5	11	1	2	(4)
11	0	......	......	12	7	11	9	6	......
12	(4)	......	......	0	6	3	3	6	......
13	......	......	......	7	2	4	7	0	......
14	......	......	......	4	2	7	1	8	......
15	......	......	......	0	7	2	7	2	......
16	......	......	......	0	9	4	5	3	......
17	......	......	......	0	6	5	0	2	......
18	......	......	......	0	0	0	0	3	......
19	......	......	......	0	6	3	3	8	......
20	......	......	......	4	4	12	0	4	......
21	......	......	......	10	10	7	0	9	......
22	......	......	......	4	0	0	0	5	......
23	......	......	......	10	2	(5)	9	0	......
24	......	......	......	0	9	......	12	12	......
25	......	......	......	0	7	......	3	3	......
26	......	......	......	0	9	......	0	2	......
27	......	......	......	5	6	......	7	4	......
28	......	......	......	16	14	......	12	4	......
29	......	......	......	6	5	......	0	2	......
30	......	......	......	0	2	......	6	2	......
July 1	......	......	......	3	7	......	2	8	......
2	......	......	......	10	0	......	7	1	......
3	......	......	......	3	0	......	3	1	......
4	......	......	......	7	4	......	8	6	......
5	......	......	......	0	6	......	2	3	......
6	......	......	......	0	3	......	4	0	......

[1] Dates on which none of the flies oviposited are omitted from the table.
[2] Died on this date; 30 eggs present in abdomen.
[3] Escaped on this date.
[4] Died on this date.
[5] Died on this date; 15 eggs present in abdomen.

TABLE XIX.—*Daily rate of oviposition of the Mediterranean fruit fly in 1914*—Contd.

Date of oviposition.	Number of eggs deposited.								
	Fly No. 1.	Fly No. 2.	Fly No. 3.	Fly No. 4.	Fly No. 5.	Fly No. 6.	Fly No. 7.	Fly No. 8.	Fly No. 9.
July 7				0	2		0	0	
8				(1)	3		9	2	
9					6		3	4	
10					2		3	4	
11					0		8	2	
12					9		4	0	
13					2		0	0	
14					5		3	5	
15					2		0	3	
17					4		0	0	
19					0		0	4	
20					0		2	0	
22					14		0	0	
23					0		3	0	
24					11		4	0	
25					7		7	0	
26					11		0	3	
27					5		0	0	
28					2		3	0	
29					3		0	0	
30					2		0	2	
31					6		0	6	
Aug. 1					3		0	4	
2					7		(2)	4	
3					4			2	
5					5			5	
6					2			5	
7					3			0	
8					0			2	
9					4			0	
10					6			0	
13					14			14	
14					3			3	
15					0			13	
16					4			0	
17					3			6	
18					5			0	
19					2			0	
21					4			0	
25					3			0	
27					3			0	
28					6			0	
29					3			0	
30					0			(3)	
Sept. 2					3				
4					(4)				
Total	191	34	86	314	622	312	426	405	3

[1] Died on this date; 16 eggs present in abdomen.
[2] Died on this date; no eggs in abdomen.
[3] Died on this date; 2 eggs in abdomen.
[4] Died on this date; 3 eggs in abdomen.

ABILITY OF FEMALES TO BEGIN OVIPOSITING REGULARLY AFTER A PERIOD OF SEVERAL MONTHS DURING WHICH HOST FRUITS WERE NOT AVAILABLE.

Females which have been kept in confinement without an opportunity to oviposit in host fruits will begin actively ovipositing when such fruits are made available. Thus, females emerging on February 28, 1914, were kept in glass jars until about 4 months old, when, on June 28, they were placed with fruits and a record kept of the eggs deposited. These data secured from 6 females show that for the days on which they oviposited they laid an average of 8.1, 4.6, 0, 6.3, 4, and 7.2 eggs. These averages compare favorably with the averages for females given an opportunity to oviposit from the time they were sexually mature until death. Fly No. 1, with its average of 8.1 eggs, deposited 22 eggs on July 26, or when it was

148 days old, and this is the largest number of eggs ever obtained by the writers during one day from any female. The flies of Table XX oviposited on the sides of their containing jars during the period up to the time they were given fruits in which to deposit eggs, but not in a normal manner.

TABLE XX.—*Daily rate of oviposition of the Mediterranean fruit fly.*

[Females emerged on February 28, 1914; hence were 4 months old on June 28, 1914. Given an opportunity to oviposit on fruit for first time on July 1.]

Date.[1]	Number of eggs deposited.						Date.[1]	Number of eggs deposited.					
	Fly No. 1.	Fly No. 2.	Fly No. 3.	Fly No. 4.	Fly No. 5.	Fly No. 6.		Fly No. 1.	Fly No. 2.	Fly No. 3.	Fly No. 4.	Fly No. 5.	Fly No. 6.
1914.							1914.						
July 1....	0	0	0	0	6	0	July 19....	6	2	......	0	0	......
2....	9	0	0	0	2	0	20....	0	5	......	4	0	......
3....	0	0	0	0	4	0	21....	5	2	......	6	0	......
4....	10	4	0	0	0	6	22....	0	8	......	7	0	......
5....	4	0	0	0	0	0	23....	0	2	......	0	0	......
6....	5	6	0	4	0	0	24....	2	6	......	13	(4)	......
7....	0	0	0	0	0	12	25....	6	2	......	0	......	......
8....	10	6	0	0	0	6	26....	22	1	......	0	......	......
9....	0	4	0	9	0	13	27....	9	2	......	0	......	......
10....	15	6	0	3	0	2	28....	9	0	......	5	......	......
11....	5	2	0	0	0	4	29....	6	7	......	0	......	......
13....	12	7	(2)	5	0	0	30....	0	5	......	0	......	......
14....	2	0	......	5	0	(3)	Aug. 1....	0	(5)	......	0	......	......
15....	7	9	......	0	0	......	2....	0	......	......	0	......	......
16....	0	8	......	0	0	......	3....	(6)	......	......	(2)	......	......
17....	13	3	......	11	0	......							
18....	5	0	......	4	0	......	Total..	162	97	0	76	12	43

[1] Dates on which none of the flies oviposited are omitted from the table.
[2] Died on this date; no eggs in abdomen.
[3] Died on this date; 11 eggs in abdomen.
[4] Died on this date; 5 eggs in abdomen.
[5] Died on this date.
[6] Died on this date; 4 eggs in abdomen.

One female emerging March 3, 1914, was isolated from fruits until August 29, or for 5 months and 26 days. When placed with fruit on August 29 she deposited 4, 5, 11, 14, 9, and 9 eggs on August 31, September 3, 4, 5, 6, and 7, or an average of 8.7 eggs for each day on which she oviposited. She deposited 11, 14, 9, and 9 eggs, respectively, on the first 4 days of the seventh month of her life, but died on the fifth day.

NUMBER OF EGGS DEPOSITED BY SINGLE FEMALES.

No attempts have been made by previous writers to determine the egg-laying capacity of the female. In 1906 Fuller assumed as a basis for data on multiplication that each female deposited 50 eggs at one time. Silvestri, after becoming familiar with the work of the writers while in Honolulu, stated that the total number of eggs deposited is not less than 300. In general, entomologists invariably have used the number of eggs found in the body as a basis for computing the egg-laying capacity.

In Table XIX the only data obtained by the writers on this subject show that the total number of eggs deposited by a single female

may be as high as 625. Fly No. 5 deposited 622 eggs and held 3 well-formed eggs in her oviducts at death. Fly No. 9, on the other hand, deposited only 3 eggs during her life. The writers believe that hardy females may deposit as many as 800 eggs, or even more, under favorable conditions. Fly No. 5, which deposited 622 eggs, lived only 153 days, while other females have oviposited for periods covering more than 10 months and might be expected to deposit more eggs. As noted above, one female deposited 11, 14, 9, and 9 eggs during the first 4 days of the seventh month of her life.

NUMBER OF EGGS DEPOSITED AT ONE TIME.

During the period from January 23 to 27, 1914, when the temperatures during the heat of the day ranged between 74° and 76° F., 15 females were observed to oviposit in apples. The time required from the instant the females started ovipositing until the ovipositor was withdrawn varied from 2 to 5 minutes, with an average of 3.8 minutes. Each puncture was found to contain from 1 to 4 eggs, and averaged 2.4 eggs.

During the warmer period of the year, on April 13, 1914, when the temperature averaged about 82° F., 8 females consumed from 2.5 to 4.5 minutes in completing the process of oviposition in apples, and deposited from 3 to 9 eggs, or an average of 5.4 eggs in each puncture.

NUMBER OF EGGS DEPOSITED IN A SINGLE EGG CAVITY.

Females oviposit repeatedly in egg cavities or punctures in table fruits, especially in those fruits in which they have difficulty in making egg chambers. Thus while females, as already noted, deposit normally only from 3 to 9 eggs in a puncture in apples at one time, cavities in apples left with females from 3 p. m. until the following morning contained from 42 to 106 eggs. As many as 300 eggs have been taken from one egg cavity in the rind of grapefruit, 129 from a cavity in a lemon, and 926 from a cavity in a mango. (Pl. XIII, fig. 3.) Observations indicate that after depositing a few eggs the females feed and move about only to return in many instances to the same spot to continue ovipositing. Frequently newly laid eggs can be found in punctures in citrus fruits in which several batches of eggs already have been hatched. Bearing in mind that only from 1 to 9 eggs are usually deposited in an egg cavity at one time, the data in Table XI will prove interesting.

OVIPOSITION BY VIRGIN FEMALES.

Females confined in jars immediately after emergence and given no opportunity to mate will deposit eggs, but none of the eggs will hatch. On September 10, 1913, 500 newly emerged virgin females were placed in a jar and began ovipositing in a normal manner on September 16, or after 6 days. One hundred and twenty-eight eggs

deposited September 16 did not hatch. The temperature during this period varied between 71 and 84° F., with a mean for the period of 78.5° F., and the relative mean humidity averaged about 66 per cent. Two hundred females emerging November 13, 1914, were confined without males and began ovipositing November 23, or after 10 days. During this period the temperature ranged between 65 and 80° F., with a mean of 74.6° F.; the relative humidity, averaging 69.2 per cent, ranged between 52 and 85 per cent. Although no daily oviposition records of these females were kept, 450 eggs deposited by them in apples on 17 different occasions when they were given an opportunity to oviposit between November 13 and March 4–5 failed to hatch. In three other experiments not one of 2,264 eggs deposited by virgin females hatched.

Virgin females which have been depositing eggs that failed to hatch may mate later and deposit fertile eggs. Thus 200 virgins emerging on March 13, 1915, oviposited quite regularly until May 14, when males were placed in the jar with them. Previous to May 14 all eggs deposited had failed to hatch. On May 16, 11 eggs were deposited; of these all hatched but 2.

INFLUENCE OF WEATHER CONDITIONS ON ADULT ACTIVITIES.

No satisfactory data on this subject can be secured out of doors in the Hawaiian Islands, as the colder temperatures which seriously affect adult activities are not to be had except at higher altitudes, where the fly is not to be found. At the Volcano House, Hawaii, at about 4,000 feet elevation, where the November mean is about 60° F. and the daily range is between 45° and 72° F., adults in jars were inactive during the early mornings and late afternoons. During the warmer period of the day adults became active and oviposited in apples hung in their jars after the temperature reached 61° F. At Honolulu, at a temperature of 65° to 67° F., 27 eggs were deposited in peaches by about 40 females, and 40 eggs by a lot of 60 females. At higher temperatures many more eggs would have been deposited under otherwise similar conditions. Adults in jars were noted to mate as usual on March 17, when the temperature was 69° F. On March 18, 9 a. m., at 67° F., adults endeavored to oviposit in apples, but did not seem to succeed in puncturing the skin. A female emerging on August 12, 1914, was placed in a large glass refrigerator, the temperature of which averaged 61° F., but varied for the period between 58° and 62° F. She was accompanied by males and deposited 3 and 6 eggs on September 12 and 20, respectively, but died on September 25. This fly was replaced by another of like age, which deposited 9, 5, 8, 4, and 6 eggs, respectively, on September 26, 27, 28, 29, and October 2.

At a mean temperature of about 78° F., adults may deposit eggs during the night, but deposition during this portion of the day has

been found most unusual. In the laboratory and out of doors adults feed and oviposit at all times of the day during the warmer months. Lounsbury has stated that in South Africa adults seek shelter beneath dried leaves, etc., in rearing cages during the colder weather, and Compere has observed adults active on orange trees in Spain during the warm hours of a day following freezing night temperatures.

LENGTH OF LIFE CYCLE.

During the warmest Hawaiian weather, when the mean temperatures average about 79.5° F., the egg, larva, and pupa stages may be completed in as few as 13 or as many as 33 days, according to the individual and its host. At this season large numbers pass through the immature stages in from 18 to 20 days. As the length of the adult life has been found to vary from a few days to 230 and 315 days, it is evident that the life cycle may be as long as 11 months when the fly passes its immature stages during the warmest portions of the year. At an average mean temperature of about 68° F., which is the coolest mean found by the writers where host fruits were readily available for study, the immature stages required from 40 to 69 days. Data already discussed indicate the difficulty in stating just what variations there may be in the length of the life cycle in still cooler climates. Thus the egg stage has been increased from 2 to 24 or 25 days by the application for 22 days of a temperature of from 48° to 53° F. A third-stage larva survived a temperature of 48° to 54° F. for 79 days, while another larva remained in the first instar 57 days at an out-of-door temperature ranging from 27° to 73° F., with a mean of about 48° F. The fruit fly has been held in the pupa stage at an out-of-door temperature ranging between 38° and 72° F., with a mean of about 53° to 54° F. for about 2 months. At Kealakekua, where the temperature ranged between 58° and 80° F., with a mean of about 68° F., 3 larvæ in very firm apples required 28, 58, and 74 days to become fully mature and leave the fruit to pupate. Add to the 74 days required for larval maturity 4 days for the egg stage and 20 days for the pupa stage, and one has a cycle for these stages of 98 days, or over 3 months. A very conservative estimate for the possible length of the immature stages, or a period sufficiently long to outlast the coldest seasons of semitropical regions, is 3 to 4 months.

SEASONAL HISTORY.

In littoral Hawaii there may be as many as 15 or 16 generations of the Mediterranean fruit fly each year, provided one considers the length of a generation as extending from the time the eggs are deposited until the female of the next generation begins to oviposit. With such an understanding a generation at Honolulu may require under the most favorable conditions as few as 17 days during the warmest weather, or as few as 31 days during the coolest winter

weather. As the females are capable of living long periods and of depositing small batches of eggs almost daily, the generations become hopelessly confused. In those portions of the islands where the winter monthly means drop to about 68° F., as in the Kona district of Hawaii at about 1,300 feet elevation, there may be not more than 10 to 12 generations. The number of generations is naturally less in colder habitats. At Strawberry, a ranch station on Hawaii at about 4,500 feet elevation, there appears to be only a single generation a year, which is evident in the last fruit to ripen on a few peach trees.

As may be expected, adults are abundant at all seasons in the littoral regions of Hawaii where host plants are grown. With the hopeless confusion of generations that exists, there can be no seasonal broods. Instead, adults may be found actively ovipositing every day of the year. That the cooler weather of the winter months does lengthen the life cycle has already been proved. This slowing down of development naturally results in the emergence of fewer adults. This is indicated by the data of Table XXI.

TABLE XXI.—*Seasonal abundance of adult Ceratitis capitata at Honolulu.*

[Average daily catch of 147 kerosene traps for the weeks indicated below, from Apr. 21, 1913, to Aug. 4, 1914. Traps exposed in Punahou district of Honolulu, east of Punahou Street and south of Wilder Avenue.]

Date.	Number.	Date.	Number.	Date.	Number.	Date.	Number.	Date.	Number.
Apr. 26	279	Aug. 2	905	Nov. 8	353	Feb. 13	58	May 23	291
May 3	347	Aug. 9	937	Nov. 15	237	Feb. 20	117	May 30	259
May 10	677	Aug. 16	763	Nov. 22	137	Feb. 28	64	June 6	389
May 17	901	Aug. 23	562	Nov. 29	132	Mar. 7	71	June 13	729
May 24	1,738	Aug. 30	439	Dec. 6	219	Mar. 14	49	June 20	1,074
May 31	1,498	Sept. 6	316	Dec. 13	324	Mar. 21	74	June 27	935
June 7	1,413	Sept. 13	219	Dec. 19	355	Mar. 28	64	July 4	1,676
June 14	1,047	Sept. 20	152	Dec. 27	240	Apr. 4	92	July 11	2,503
June 21	855	Sept. 27	141	Jan. 2	176	Apr. 11	123	July 18	2,002
June 28	1,084	Oct. 4	167	Jan. 9	48	Apr. 18	150	July 25	1,677
July 5	769	Oct. 11	200	Jan. 16	84	Apr. 25	124	Aug. 1	964
July 12	723	Oct. 18	200	Jan. 24	46	May 2	188	Aug. 4	523
July 19	769	Oct. 25	205	Jan. 31	51	May 9	343		
July 26	727	Nov. 1	270	Feb. 7	72	May 16	455		

These data on the number of males captured in 147 traps in an area equal to about four city blocks are taken as indicating the relative abundance of adults in a single year, in a section of Honolulu where many host trees occur. The adults are most numerous during late May, June, and July, and less numerous during January, February, and March. The numerical abundance of adults in Honolulu, where the climate never seriously retards development, is affected more by the numerical abundance of ripening host fruits, which is greatest during the early summer and least during the winter. The fact that there are relatively fewer adults during the winter months is of no practical value to growers of fruit in Hawaii, since the smaller amount of fruit ripening at that season is nearly as badly affected as are the fruits ripening during the summer.

NATURAL CONTROL.

No striking examples of control by natural agencies were evident in Hawaii previous to the introduction of parasites. As indicated below, there are several minor factors of natural control, aside from parasites, but they are of no practical value under Hawaiian conditions. A certain amount of natural mortality occurs among larvæ and pupæ, but it is small under ordinary conditions. It has been suggested that there occurs an unusually high mortality among pupæ formed by larvæ developing in such juicy fruits as the mango, but this has been disproved by experimental work. The high rate of mortality among pupæ derived from mangoes in laboratories is produced by the severe sifting process necessary to separate the pupæ from the wet sand in which they form, or from insanitary conditions.

EXCESSIVE HEAT.

The larvæ within fruits which lie in the direct sunlight after they have fallen are killed in large numbers. Often all the larvæ in the portion of a fruit exposed to the sun will be found dead. During August, 1914, mangoes were exposed to the sun for two days over sand in shallow trays. Examinations later proved the 17 fruits to contain 17 living and 84 dead third-instar larvæ, with 14 larvæ dead on the surface of the fruits. One larva died when partly out of a fruit and 103 succeeded in pupating normally. In 23 other fruits held in the shade as a check there were found 168 living and 9 dead third-instar larvæ, and beneath them 167 pupæ. While every larva in certain of the fruits exposed to the sun was killed, it is evident the many larvæ in the protected portion of the fruit may escape and pupate normally.

PREDACIOUS ENEMIES.

Although Compere reported certain staphylinid beetles in Brazil and forficulids in India attacking larvæ of fruit flies, they seem to be of little value as practical checks. The writers have observed earwigs within decayed areas of fruits infested by *C. capitata* and drosophilid larvæ in Hawaii under conditions which indicated that they were feeding upon fruit-fly larvæ. Earwigs confined in jars within the laboratory were observed to attack and devour well-grown *C. capitata* larvæ. Their numbers, however, are far too small to have any effect upon fruit-fly increase..

The small brown ant (*Pheidole megacephala* Fab.), known also as the Madeira house ant and the harvester ant, unquestionably is an important factor in natural control. This ant, which inhabits most abundantly the littoral regions, is frequently found swarming over and throughout fallen fruits, killing many larvæ as they leave the fruit to pupate. Ants were observed to remove from a fallen ball kamani nut 86 medium sized *C. capitata* larvæ between 11.18 and 11.58 a. m., April 5, 1913. An examination at the end of this period

showed that 34 larvæ in a firm portion of the flesh had escaped attack. Within the laboratory this ant has demonstrated its ability to destroy pupæ.

CLIMATIC CONTROL.

There is little opportunity in Hawaii to study the effect of adverse climatic conditions upon the Mediterranean fruit fly. Development appears to progress most rapidly after the Hawaiian temperature means reach 75° or 76° F. At a mean of 68° F. the developmental period is about doubled. A temperature ranging between 58° and 62° F. has no detrimental effect upon the development as shown by the emergence of adults from pupæ held in a well-lighted refrigerator. These emergence data, recorded in Table XXII, and supplemented by four other experiments, indicate that the pupa stage may be increased from 38 to 41 days, or that, at this temperature, the length of development may be increased to three or four times the normal during the warmest weather. Only 9 out of 39,500 pupæ held at a temperature of from 49° to 51° F. yielded adults within refrigeration, while the remainder died. All cold-storage data obtained by the writers indicate that approximately 50° F. is the temperature at which little or no development can take place and below which complete mortality occurs if exposures are continued sufficiently long.

TABLE XXII.—*The effect upon pupal development of the Mediterranean fruit fly of 58° to 62° F.*

Days in storage.	Age of pupæ when placed in storage and number yielding adults.									
	½ day.	1 day.	2 days.	3 days.	4 days.	5 days.	7 days.	8 days.	9 days.	10 days.
1										27
2								11	334	1,290
3								3	949	657
4								20	1,469	28
5							10	135	96	14
6							8	2,066	38	
7						4	36	918	37	
8						2	687	55	2	1
9						10	2,118	13	2	1
10						23	479	4	1	1
11					1	18	43	4		1
12				2	2	604	95		6	
13			6	1	5	930	5		1	
14			4		6	640				
15		1	3		1	773				
16		2	3	4	14	169				
17			5		33	9				
18			15	2	566	53				
19		2	1		1,324	21				
20		4	29	25	381	19				
21			131	319	38	5				
22	1	4	203	1,316	4	3				
23	4	6	399	335	2					
24	12	4	1,477	21	1	1				
25	9	36	1,013	6	1					
26	16	392	158							
27	44	1,515	15	1						
28	367	708	4							
29	1,217	49								
30	159	3								
31	25									
32	11									
33	5									
34	1									
38	1									

This conclusion drawn from cold-storage experiments[1] will be found, the writers believe, to hold true for out-of-door conditions. During January to March, 1914, the writers exposed infested apples on the slopes and summit of the extinct volcano Hualalai, at elevations of about 5,000 and 8,250 feet. At about 5,000 feet elevation, where the temperature ranged from 31° to 64° F., during January, with a mean of about 51° F., the larval development was apparently held at a standstill, although as the minimum temperatures increased with the approach of spring, larvæ were able to more than hold their own. During March, when the daily temperatures ranged from 40° to 70° F., with a mean of about 55° F., development of all stages occurred attended by no unusual mortality. At 8,250 feet elevation, where the minimum temperatures ranged from 27° to 43° F., with the maximums between 42° and 70° F., and a mean for the maximums and minimums of about 48° F., no development took place. Instead, the mortality was very great. As spring approached, the temperatures increased until, during March 20 to 25, they ranged between 38° and 67° F. The result of examinations made of infested apples after indicated periods of exposure are given in Table XXIII.

TABLE XXIII.—*Mortality among eggs and larvæ of the Mediterranean fruit fly in apples exposed on the summit of Hualalai from Jan. 31 until date of removal.*

Fruit removed from mountain.	Date of examination.	Eggs unhatched.	Larvæ.					
			First instar.		Second instar.		Third instar.	
			Alive.	Dead.	Alive.	Dead.	Alive.	Dead.
Feb. 4	Feb. 5	....	221	1	....	....	....	....
Feb. 12	Feb. 15	....	334	20	522	82	33	....
Feb. 17	Feb. 19	5	3	115	97	16	2	....
Feb. 25	Feb. 26	28	27	350	37	434	3	154
Mar. 4	Mar. 6	10	55	481	33	216	....	....
Mar. 17	Mar. 19	2	3	315	....	278	6	500
Mar. 26	Mar. 27	24	1	872	2	56	2	965

These data prove that at the Hualalai temperatures a very few larvæ may survive, although by far the largest percentage are killed.

The data given elsewhere (p. 108–111) on the effect of cold storage and freezing temperatures upon the various stages of the fruit fly prove how easily this pest can withstand for short intervals colder temperatures than are likely to occur for long periods in fruit-fly countries. Thus the egg itself has been known to withstand a freezing temperature of from 24° to 30° F. for 7 days and still hatch. These low temperatures, however, produce a very great mortality that has been emphasized by data already published.

That adverse climatic conditions have been a valuable aid in curbing fruit-fly attack is appreciated by entomologists dealing with this

[1] See Journal of Agricultural Research, v. 5, 1916, p. 657–666; v. 6, 1916, p. 251–260.

pest. Newman, in Western Australia, has found that a very large percentage of the pupæ are killed by a cold, wet winter when the ground is frequently flooded. Such conditions so lessen the abundance of the fruit-fly that there are relatively few flies, numerically speaking, to infest the early fruits of the succeeding season. On the other hand, unusually severe outbreaks of the pest in both South Africa and Australia have been attributed to exceptionally dry, mild winters which made it possible for many adults to be present the following spring to start large early summer generations. The successes attributed to clean cultural methods for the eradication of the fruit fly in the apple orchards at Harvey, Western Australia, and possibly in New Zealand and Tasmania, may be due quite as much to the work of adverse climatic conditions. The effect of climate upon fruit-fly development can not be intelligently interpreted, inasmuch as previous writers have not included climatological data with their statements.

PARASITES.

CERATITIS AND DACUS PARASITES.

Literature contains numerous references to parasites reared from various species of fruit flies. The only parasites discussed at length here are those which have been successfully introduced and give promise of being useful as factors in controlling *Ceratitis capitata*. Of the parasites at present being reared from *Ceratitis capitata* under natural conditions, *Opius humilis* is the only one reared originally from this fruit fly.[1] All other parasites now known to attack *Ceratitis capitata* in the field in Hawaii have adapted themselves to this host. There appears to be no reason why certain others of the parasites already reared from other fruit flies may not be used ultimately in controlling the Mediterranean fruit fly. Silvestri records and discusses the following parasites studied by him:

BRACONIDÆ.

Subfamily Opiinae: *Opius concolor* Szepligeti (ex *Dacus oleae*, Susa, Tunisia), *O. dacicida* Silvestri (ex *Dacus oleae*, Eritrea), *O. lounsburyi* Silvestri (ex *Dacus oleae*, Transvaal), *O. dexter* Silvestri (ex *Dacus longistylus*, Dakar, Senegal), *O. perproximus* Silvestri (ex *Dacus brevistylus* and *Ceratitis giffardi*, Kotonou and Segboroue, Dahomey), *O. perproximus modestior* Silvestri (ex *Ceratitis nigerrima* Aburi, Gold Coast, and Olokemeji, Nigeria), *O. humilis* Silvestri (ex *Ceratitis capitata*, Constantia, Cape Colony), *O. inconsuetus* Silvestri (ex *Ceratitis tritea*, Olokemeji, Nigeria), *O. inquirendus* Silvestri (identity of host unknown, Victoria, Kamerun), *O. africanus* Szepligeti (ex *Dacus oleae*, South Africa and Transvaal), *O. africanus orientalis* Silvestri (ex *Dacus oleae*, Eritrea), *Hedylus giffardii* Silvestri (ex *Ceratitis punctata*, Conakry, French Guinea), *Diachasma fullawayi* Silvestri (ex *Ceratitis giffardi* and *tritea*, Dakar, Senegal, Olokemeji, Nigeria, and Kakoulima, French Guinea), *D. fullawayi robustum* Silvestri (ex *Dacus bipartitus*,

[1] The writers reared a single specimen of a parasite from a *C. capitata* pupa which was identified by D. T. Fullaway as *Spalangia* sp. It seems probable that this was primarily a parasite of some other dipteron, as no other specimens were reared.

Conakry, French Guinea), *D. tryoni* Cameron (ex *Bactrocera tryoni*, New South Wales and Queensland, Australia), *Biosteres caudatus* Szepligeti (ex *Ceratitis giffardi, tritea, nigerrima, anonae, antistictica*, and *Dacus bipartitus* and *brevistylus*, West Africa).

Subfamily Sigalphinae: *Sigalphus daci* Szepligeti (ex *Dacus oleae*, Transvaal).

Subfamily Braconinae: *Bracon celer* Szepligeti (ex *Dacus oleae*, Stellenbosch and Wellington, South Africa).

PROCTOTRUPIDAE.

Subfamily Diapriinae: *Galesus silvestrii* Kieffer (ex *Ceratitis anonae*, Olokemeji, Nigeria; ex *C. nigerrima*, Aburi, Gold Coast; ex *C. giffardi*, Kotonou, Dahomey), *G. silvestri robustior* Silvestri (ex *Ceratitis punctata*, Conakry, French Guinea), *Trichopria capensis* Kieffer (ex *C. capitata*, Constantia, Cape Colony).

CHALCIDIDAE.

Subfamily Chalcidinae: *Dirhinus giffardii* Silvestri (ex *Ceratitis anonae*, Olokemeji, Nigeria), *D. ehrhorni* Silvestri (ex *Ceratitis giffardi*, Olokemeji, Nigeria).

Subfamily Pteromalinae: *Spalangia afra* Silvestri (ex *Ceratitis anonae*, Olokemeji, Nigeria).

Subfamily Eulophinae: *Tetrastichus giffardii* Silvestri (ex *Ceratitis antistictica, giffardi, colae*, and *Dacus bipartitus*, West Africa), *T. oxyurus* Silvestri (ex *Ceratitis tritea*, Olokemeji, Nigeria), *T. giffardianus* Silvestri (ex *Ceratitis giffardi*, Nigeria and Dahomey), *T. dacicida* Silvestri (ex Dacus *bipartitus*, West Africa), *Syntomosphyrum indicum* Silvestri (ex Dacus, India).

In addition to these, Ihering records the following parasites from Brazilian fruit flies: *Eucola* (*Hexamerocera*) *brasiliensis* Ashmead, *Biosteres brasiliensis* Szepligeti, *B. areolatus* Szepligeti, *B.* sp., and *Opiellus trimaculatus*. Gowdey states that he reared a single chalcidid parasite from *C. capitata* pupæ in one out of many attempts to secure parasites.

To the foregoing list of fruit-fly parasites should be added *Pachycrepoideus dubius*, introduced by D. T. Fullaway at Honolulu from the Philippines during the early part of 1914. Although a parasite of a dung fly (species not recorded) and introduced to aid in the control of the horn fly, it has since been reared from *C. capitata* pupæ by the writers.

GENERAL HISTORY OF PARASITE INTRODUCTIONS.

Attempts have been made to introduce fruit-fly parasites to control *Ceratitis capitata* from India into Western Australia by Compere, from India into South Africa via Western Australia by Lounsbury, from India into Italy by Silvestri, from Brazil into South Africa by Lounsbury and Fuller, and from Africa and Australia into the Hawaiian Islands by the Hawaiian Board of Agriculture and Forestry. So far as is at present known, these attempts have failed in all countries except in the Hawaiian Islands. Compere arrived at Perth, Australia, on December 7, 1907, with fruit-fly pupæ secured at Bangalore, India. Although he reared from these pupæ an estimated 2,000,000 specimens of *Syntomosphyrum indicum* and 300 specimens representing two braconid species and was able to make numerous liberations in badly affected areas, the West Australian

fruit growers have received no appreciable benefit. Newman, in 1908, stated that he had collected in the field during that year pupæ of *C. capitata* parasitized by the introduced parasites. In 1909 he stated, however, that the chalcid and braconid parasites, although liberated for over 15 months, had not yet produced evident results, and in 1911 he wrote that although *Syntomosphyrum indicum* had been reared and liberated in large numbers during the previous four years, it did not appear to be established and there seemed little prospect of favorable results.

In 1905 Lounsbury and Fuller investigated fruit-fly conditions in Brazil and secured parasitized pupæ of *Anastrepha fratercula*, but they were unable to reach South Africa with living parasites. Parasitized pupæ of *C. capitata* were sent from Western Australia to Durban and Cape Town during 1908, but Lounsbury reported in 1909 that the introduction was unsuccessful. Silvestri, on his return in 1913 to Hawaii from West Africa, left in South Africa specimens of Dirhinus and Galesus, but they were unable to survive the following winter according to Lounsbury. Silvestri states that although he introduced *Syntomosphyrum indicum* into Calabria, Italy, he had not been able to prove that it had become established.

INTRODUCTION OF PARASITES INTO HAWAII.

The search for and discovery, the introduction, and subsequent establishment of parasites of *Ceratitis capitata* in the Hawaiian Islands form an interesting and important chapter in the history of this world-wide pest. The writers are able to state definitely, as a result of their biological work between September, 1912, and May, 1913, that no parasites of *Ceratitis capitata* were present in Hawaii up to the time when the first introductions were made in May, 1913, if we except the *Spalangia* sp. referred to on page 80 (footnote). At the present time, January 1, 1916, all larval parasites (*Opius humilis*, *Diachasma tryoni*, *D. fullawayi*, and *Tetrastichus giffardianus*) that have been liberated are being recovered in the field, and practically every lot of larvæ reared from samples of fruit collected in the littoral regions are found to be parasitized by one or more parasites. From exceptional lots all four parasites have been reared. The two pupal parasites, the proctotrupid *Galesus silvestrii* and the chalcid *Dirhinus giffardii*, have never been recovered by the writers and will not be the subject of further discussion.

The parasites at present attacking *Ceratitis capitata* in Hawaii have been introduced by the Hawaiian Board of Agriculture and Forestry. Much credit is due Mr. W. M. Giffard, who, as president of this board, was able to make arrangements for the Silvestri and the Fullaway-Bridwell expeditions to Africa. Dr. Silvestri set out from Italy during

July, 1912, and arrived at Honolulu May 16, 1913. During this time he searched for parasites in the West African States of Senegal, French Guinea, Nigeria, Kamerun, Gold Coast, Dahomey, the Kongo, and Angola; also in South Africa and in Australia. It is needless to say that Dr. Silvestri was unable to make a complete survey of fruit-fly conditions during so short a time, yet his investigations were successful, not only because they cleared the way for the Fullaway-Bridwell expedition, but also because they resulted in the introduction and establishment of *Opius humilis* and *Diachasma tryoni*. Messrs. D. T. Fullaway and J. C. Bridwell sailed from Honolulu on the second expedition during June, 1914, and arrived at Lagos, Nigeria, on July 24. On August 19 Mr. Fullaway took the parasitized material collected by the expedition at Olokemeji, near Lagos, and sailed for Teneriffe, Canary Islands, where he was able to use *C. capitata* in rearing additional specimens of the parasites emerging from the Nigeria material. With fresh material, Fullaway sailed from Teneriffe September 27 for Hawaii via Havana, Key West, Jacksonville, New Orleans, and San Francisco, arriving at Honolulu on October 27. On arrival he had living material of *Tetrastichus giffardianus*, *Diachasma fullawayi*, *Opius* sp., and *Spalangia* sp.

Mr. Bridwell proceeded from Lagos with an excellent supply of parasitized material, particularly of what appeared to be a new opiine collected at Olokemeji during the period August to October, 1914, to Honolulu via Cape Town and Australia. Unfortunately, he was overtaken before reaching Cape Town with a severe illness which necessitated stops for recuperation in South Africa and Australia of sufficient duration to make it impossible for him to bring living parasites with him to Hawaii.[1]

It has already been stated that early in 1914 Mr. D. T. Fullaway introduced at Honolulu a species of dung-fly parasite, *Pachycrepoidius dubius* Ashm. (Pl. XX, fig. 2) which was reared in small numbers by the writers from *C. capitata* pupæ during 1915.

TETRASTICHUS GIFFARDIANUS SILV.

HISTORY.

Tetrastichus giffardianus Silv. was confused with *T. giffardii* Silv., both in the mind of its author and in those of entomologists in Hawaii. The latter species was first reared from *Ceratitis colae* by the entomologist (1912–13) of the agricultural station at Aburi, Gold Coast, Africa. These specimens were identified by Dr. Silvestri as

[1] For full accounts of these parasite expeditions one should consult: Report on an Expedition to Africa in Search of the Natural Enemies of Fruit Flies. F. Silvestri. Bull. 3, Haw. Bd. Agr. and Forestry, Feb., 1914; Report of the Work of the Insectory. D. T. Fullaway. In Rept. Div. Ent. Haw. Bd. Agr. and For., for the biennial period ending Dec. 31, 1914.

new to science. Silvestri reported having reared *giffardii* during the period November, 1912, to February, 1913, from *Ceratitis antistictica* and *C. giffardii* at Olokemeji, Southern Nigeria; from *C. giffardii* at Kotonou, Dahomey, and from *Dacus bipartitus* at Victoria, Kamerun. Silvestri was unable to keep adults alive during the passage from West Africa to Honolulu.

In March, 1915, Silvestri published the description of *T. giffardianus*, stating that previous to then he had confused the species with *giffardii*. *T. giffardianus* was reared by Silvestri from *Ceratitis giffardii* Bezzi, collected at Olokemeji, southern Nigeria, and at Kotonou, Dahomey.

It was *T. giffardianus* Silv. and not *T. giffardii* that was collected by the Fullaway-Bridwell expedition and introduced into Hawaii at Honolulu on October 27, 1914. This fact should be borne in mind, because much of the literature dealing with parasites of *C. capitata* in Hawaii refers to *T. giffardianus* as *T. giffardii*. References to Tetrastichus as a parasite of *Ceratitis capitata* in Hawaii should be interpreted to refer only to *T. giffardianus*.

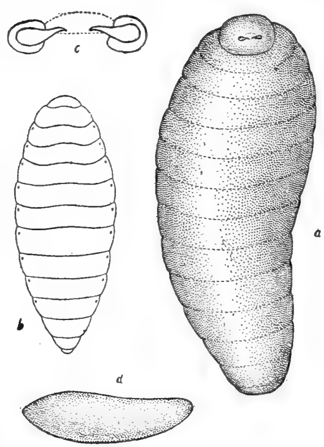

FIG. 17.—*Tetrastichus giffardianus*: *a*, Ventral view of mature larva; *b*, dorsal view of same, showing spiracles; *c*, mouth hooks or man dibles; *d*, egg. Greatly enlarged. (Original.)

Fullaway introduced into the Hawaiian Islands 300 living specimens of both sexes of *T. giffardianus*. By December 31, or after about two months of breeding in the laboratory, these 300 had increased to 21,431 specimens. Of these, 18,050 were liberated on Oahu, Hawaii, and Kauai by January 1, 1915. Although many thousand specimens have been liberated since December, 1914, none had been recovered as late as February, 1916, from any island except Oahu.[1] In Honolulu specimens have been reared from widely separated points, which would seem to indicate that this parasite has been established successfully. The first recoveries were made by the writers during September, 1915, in Honolulu.

DESCRIPTION.

Adult.—Both sexes of the adult are black with a slightly dark-green iridescence. The antennæ are rather dark, as are also the

[1] Exception: One lot of 46 pupæ of *C. capitata* from coffee cherries collected June 18, 1915, at Kainaliu, Hawaii, showed a parasitism of 63 per cent by *Opius humilis*, 30.4 per cent by *Diachasma tryoni*, and 2.1 per cent by *Tetrastichus giffardii*.

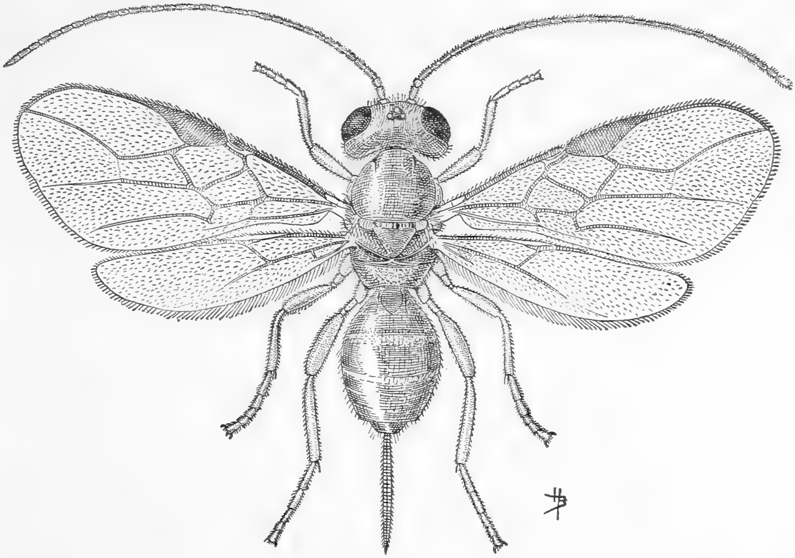

FIG. 1.—OPIUS HUMILIS: ADULT FEMALE. GREATLY ENLARGED. (ORIGINAL.)

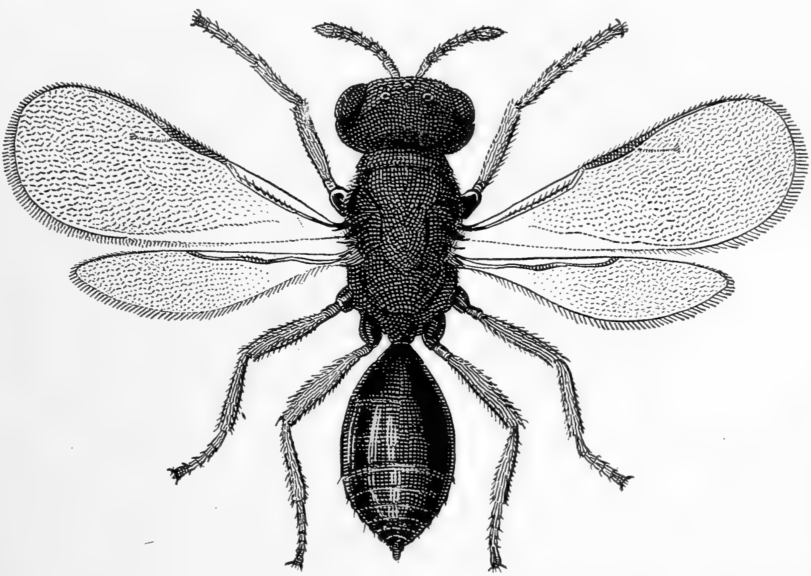

FIG. 2.—PACHYCREPOIDEUS DUBIUS: ADULT FEMALE. GREATLY ENLARGED. (ORIGINAL.)

PARASITES OF THE MEDITERRANEAN FRUIT FLY.

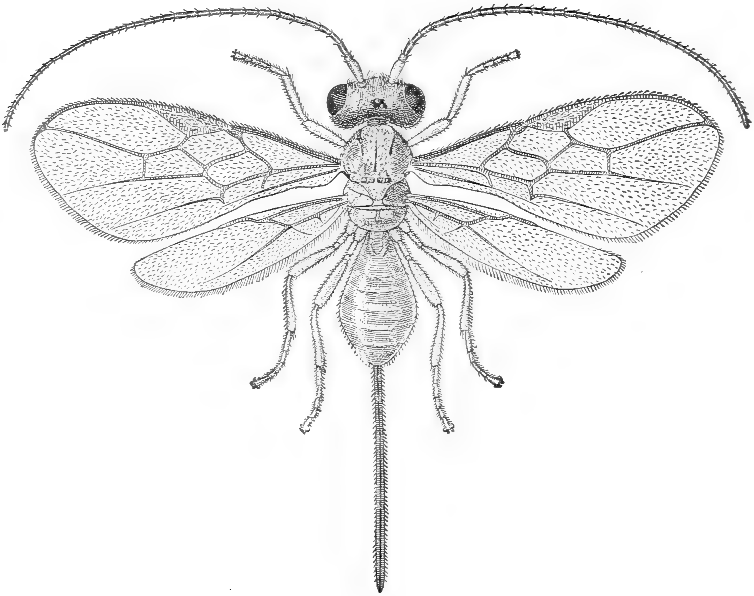

FIG. 1.—DIACHASMA FULLAWAYI: ADULT FEMALE. GREATLY ENLARGED. (ORIGINAL.)

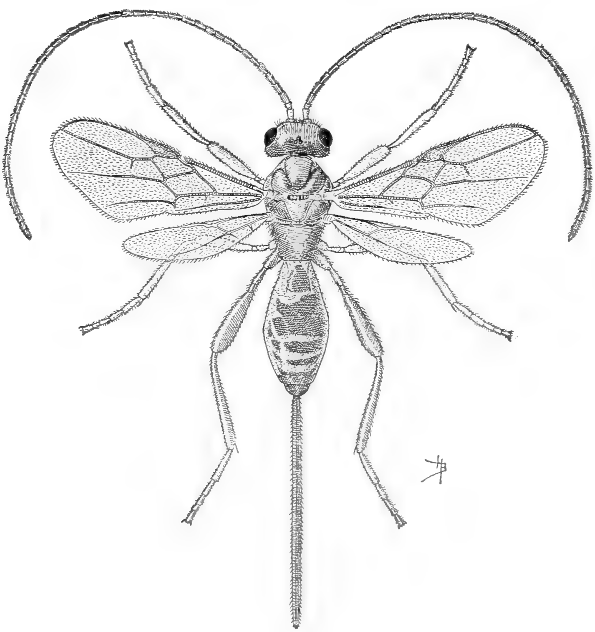

FIG. 2.—DIACHASMA TRYONI: ADULT FEMALE. GREATLY ENLARGED. (ORIGINAL.)

PARASITES OF THE MEDITERRANEAN FRUIT FLY.

femora, but the tibiæ and tarsi are more yellowish. Length of body, about 2 mm. For the original description see Bolletino del Laboratorio di Zoologia, Portici, volume 9, page 374 (1914–15).

Egg.—The egg is pure white, about 0.11 mm. long, and shaped as shown in figure 17, *d*.

Larva.—The well-grown larva is white and grub-like, about 1.8 mm. long (fig. 17, *a*). When viewed from above, spiracles are evident on segments 3–9 (fig. 17, *b*). The mandibles are microscopic (fig. 17, *c*). When first hatched, larvæ are about 0.28 to 0.3 mm. long.

Pupa.—The pupa is about 1.9 mm. long. (See fig. 18.)

BIOLOGY.

Silvestri was unable to keep adults of *giffardii* (or *giffardianus* ?) alive for more than 15 days. His original statement that the female deposits her eggs within the eggs or young larva of the host has been proved by Fullaway and the writers to be incorrect. Oviposition by *T. giffardianus* occurs largely in the well-grown larvæ as in the case of the Opiinae. The adult parasite will enter larval chambers and breaks in the host fruit in search of fruit-fly larvæ as has been proved by the writers under laboratory conditions, and accumulating data seem to indicate that adults oviposit for the most part in larvæ within fruit already fallen to the ground. Adults are capable of beginning oviposition as soon as they emerge from the puparium of the host. The female does not necessarily make a new puncture in the epidermis of its host for each egg deposited; in one instance 41 eggs were deposited through 17 punctures. When the female comes upon a larva within a larval channel, she deposits her eggs at points about its posterior portion, but when access to the larva can be had through a thin membrane of the host fruit, she may deposit her eggs in any portion of the body. The punctures in the epidermis are evident as small dark brown depressions. Of a total of 322 adults reared from 20 pupæ, 194 were females and 128 were males; the number of adults reared from single pupæ varied from 1 to 35.

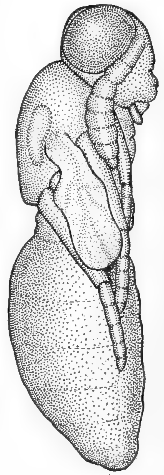

FIG. 18.—*Tetrastichus giffardianus:* Lateral view of pupa. Normal length, 1.9 mm. (Original.)

When the temperature ranges between 66° and 82° F., with a mean of about 74° F., eggs hatch in about 3 days, the larvæ become full grown in about 8 days, and the pupæ yield adults in from 11 to 15 days.

Opius humilis Silv.

HISTORY.

Opius humilis Silv. (Pl. XX, fig. 1) was first reared and described by Silvestri from pupæ of *Ceratitis capitata* collected at Constantia, Cape Colony, Africa, during March, 1913. This parasite does not appear to be an effective factor in the control of *Ceratitis capitata* under South African conditions. Silvestri reared only a few specimens of which he had only 5 representing both sexes in a living condition when he arrived at Honolulu, May 16, 1913. Although after Silvestri arrived at Honolulu he was able to rear fresh material, the danger that the progeny would be males only was so great that 3 females, with males, were liberated in the coffee fields of Kona, Hawaii, on June 12, 1913. This precaution alone saved the species from extinction in the islands, as the progeny of the specimens kept in the laboratory proved to be males. During October, 1913, large numbers of *Opius humilis* were recovered from *Ceratitis capitata* larvæ in coffee cherries in Kona, Hawaii, and it was found that the species was well established. From the specimens recovered from Kona, colonies were reared and liberated in other parts of the islands. No specimens were liberated in Honolulu until December, 1913. By July, 1914, *humilis* was found well established in the city, and by December of that year data already published[1] prove it to have become very abundant and widespread.

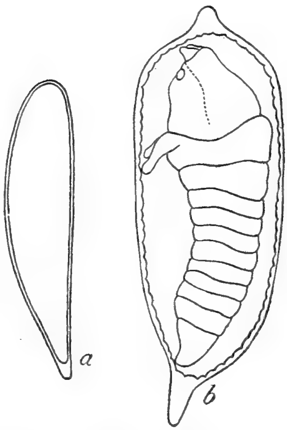

FIG. 19.—*Opius humilis: a*, Egg 1 day old, length 0.45 mm.; *b*, egg 3 days old, length 0.8 mm. (Original.)

DESCRIPTION.

Adult.—The original description of the adult by Silvestri is as follows:

♀ Body ochraceous in color, antennæ brownish-fulvous, wings hyaline with the veins brownish and the central part of the stigma ochraceous-ferruginous, legs with pretarsi brown and the posterior tarsi also in great part brown. Head scarcely more than one-third wider than long, hairy; face with a slight median carina; epistoma slightly elevated; antennæ a little longer than the body, with 35 segments; eyes a little more than twice as long as wide, their lower margin attaining the level of the superior margin of the epistoma. Mesothoracic scutum entire, smooth, with very short parapsidal furrows anteriorly; transverse prescutellar sulcus with eight small

[1] Back, E. A., and Pemberton, C. E. Parasitism among the larvæ of the Mediterranean fruit fly (*C. capitata*) in Hawaii during 1914. Rept. Hawaii Bd. Agr. and For., Dec. 31, 1914.

pits; scutellum smooth with 3 or 4 small pits and a large deep one; metanotum with a short median carina, on the submedian part shortly crenulate before the sublateral pit; propodeum with a median carina, in some specimens divided from the base into two almost contiguous parallel arms posteriorly diverging, the remainder rugose; mesopleural sulcus falveolate. Wings with venation as shown in figure [Pl. XX, fig. 1.] Abdomen with the first segment rugose on the dorsum, the remainder smooth, with a few hairs; ovipositor almost straight, a little shorter than the abdomen.

Length of body, 2.6 mm.; width of thorax, 0.79 mm.; length of antennæ, 3.3 mm.; length of front wing, 2.6 mm.; width of same, 1.15 mm.; length of third pair legs, 2 mm.; length of ovipositor, 1.15 mm.

Egg.—The egg when first deposited is about 0.45 mm. long, white and of the shape indicated in fig. 19, *a*. As the embryo develops, the entire egg increases in size until when between 2 and 3 days old (Feb., 1916) it becomes about 0.8 mm. long, and over twice as wide as when first deposited, with a protuberance at the anterior end. The developing embryo may be readily seen through the egg membranes (fig. 19, *b*).

Larva.—The white, newly hatched larva is about 1 mm. long. It has a rather large head and 12 distinct body segments. (See fig. 20.) On the anterior ventral portion of the first body segment is a pair of appendages (fig. 20, *b*, *d*), which the larva does not appear to be able to move at will or to use as an aid to locomotion. The jaws are very large and strong, being much larger in proportion than in the succeeding instars (fig. 20, *c*). The ventral portion of the head, behind the mandibles, is rather strongly chitinized, forms a support for the latter, and bears on its anterior margin two toothlike projections. On the ventral anterior portion of the head are two fleshy antennal protuberances. The thoracic appendages and large mandibles are lost after the larva molts into the second instar.

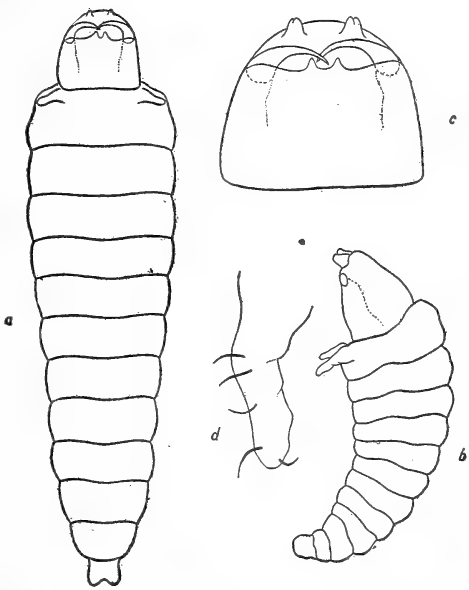

FIG. 20.—*Opius humilis*. Larva: *a*, Ventral, and *b*, lateral view of newly hatched larva; *c*, ventral aspect of head of same; *d*, enlarged thoracic appendage. (Original.)

Pupa.—The pupa is about 2.3 mm. long (fig. 21). It is very readily distinguished from the other opiine pupæ by the short ovipositor sheath.

Diachasma tryoni Cameron.

HISTORY.

Diachasma tryoni Cameron (Plate XXI, fig. 2) is primarily a parasite of the Queensland fruit fly (*Bactrocera tryoni*) and was first reared by Brooks and Gurney in New South Wales during 1908, and described as a new species by Cameron in 1911. Of 1,575 pupæ of *Bactrocera tryoni* secured by Gurney from 18 different lots of fruits during the period from January, 1910, to February, 1911, 30.2 per cent were parasitized; the highest percentage of parasitized being 52.2 per cent of 136 pupæ secured at Narara during February, 1910. During April, 1913, at Gosford the parasitism equaled 70 per cent. While *Diachasma tryoni* in Australia attacks principally the Queensland fruit fly, it has been definitely reared there from *Ceratitis capitata* under field conditions, and the indications are strong that it may attack also the island fruit fly, *Trypeta musae* Frogg. It was the opinion of Gurney that this parasite might, upon occasion, become a valuable check upon *C. capitata*.

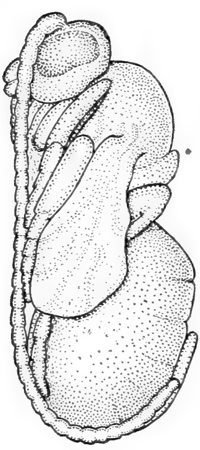

FIG. 21.—*Opius humilis:* Lateral view of pupa. Greatly enlarged. (Original.)

While en route to Honolulu from West Africa, Silvestri, aided by Gurney, secured pupæ of *Dacus tryoni* in New South Wales. From these pupæ Silvestri reared adults of *Diachasma tryoni*, of which he succeeded in introducing at Honolulu 4 female and 3 male specimens on May 16, 1913. Silvestri soon found in his rearing experiments in Honolulu that the progeny were largely of the male sex, hence 4 females, with males, were liberated June 12 in the Kona coffee district of Hawaii, 3 females, with males, on July 4 at Waianae, and 9 females, with males, on July 11 in Kona, Hawaii. As all the progeny of the remainder of the material held at the insectary were males, the specimens of this parasite now in Hawaii are the progeny of 24 females liberated during June and July, 1913. The first recovery of *Diachasma tryoni* was made by Ehrhorn during August, 1914, from *C. capitata* pupæ from the Kona district of Hawaii. During October, 1914, a systematic collection of infested coffee cherries throughout this district proved *tryoni* to be thoroughly established. Although 3 females were liberated at Waianae, Oahu, on July 4, 1913, no specimens were liberated in and about Honolulu until early in 1915. Yet by October, 1915, this parasite was being reared [1] in small numbers from *C. capitata* pupæ obtained in various parts of the city.

[1] Back, E. A., and Pemberton. C. E., Parasitism among the larvæ of the Mediterranean fruit fly (*C. capitata*) in Hawaii during 1915. Jour. Econ. Ent., v. 9, 1916, p. 306–311.

DESCRIPTION.

Adult.—Silvestri's description of the adult is as follows:

♀. Head, thorax, first segment of the antennæ, front and middle legs testaceous-ferruginous in color; abdomen in great part brown or shining blackish brown; wings slightly infuscate, with the stigma and veins brown; third pair of legs entirely brown from apex to trochanters. Head a little broader than the thorax, about one-fourth wider than long with a slight median longitudinal ridge on the face, epistoma slightly semicircularly produced in the middle; antennæ longer than the body, with 45 segments; eyes small, twice as long as wide. Mesothoracic scutum with the parapsidal furrows smooth and deep, convergent, uniting in a deep median pit situated a little before the posterior margin; transverse prescutellar sulcus with a large pit divided into four small ones and each provided also with an incomplete posterior division; scutellum smooth; parascutellar pit with an internal scarcely visible crenulation; metanotum with a short very slight median carina flanked by two small depressions, lateral pit with an abbreviated carina; propodeum with a small anterior conical protuberance directed forward, median and submedian surface almost smooth, a little rugose at the sides and posteriorly, mesoplural sulcus crenulate. Wings with the venation shown in figure [Pl. XXI, fig. 2.] Abdomen with all the segments smooth and shining, with few hairs; ovipositor about as long as the body. Length of body, 3.5–4.5 mm.; width of thorax, 0.95 mm.; length of antennæ, 5 mm.; length of front wing, 4 mm.; width of same, 1.7 mm.; length of third pair of legs, 4.4 mm.; length of ovipositor, 4.5 mm.

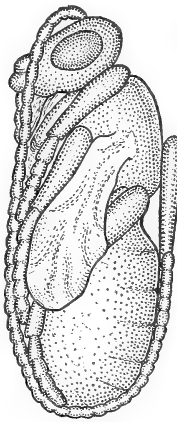

FIG. 22.—*Diachasma tryoni:* Lateral view of pupa. Greatly enlarged. (Original.)

♂. Similar to the female.

Larva.—Oval in form, whitish, with the skin smooth and apparently naked, but under strong magnification may be seen to be provided with dense, small, and slender points. Mandibles short, slightly arcuate and gradually attenuate, terminating in a point. Antennæ very short. Length of body, 3 mm.; width, 1.6 mm.

Egg.—The egg of *Diachasma tryoni* is glistening white, about 0.57 mm. long and distinctly attenuated at each end.

Larva.—The newly hatched larva, which is about 1 mm. long, is similar to that of *Opius humilis* (fig. 20, *a*, *b*) and *Diachasma fullawayi* in general shape and in the possession of two ventral appendages upon the first body segment. The proportionately large jaws are similar to those of newly hatched larvæ of *humilis* and *fullawayi* but slight distinguishing characters can be found in the large chitinous ventral plate of the head.

Pupa.—The young pupa is white in color, about 4 mm. long, 1.7 mm. wide, and may be distinguished from that of either *humilis* or *fullawayi* by the length of the ovipositor. (Fig. 22.)

DIACHASMA FULLAWAYI SILV.

HISTORY.

Diachasma fullawayi (Plate XXI, fig. 1) was first reared and described by Silvestri from pupæ formed by larvæ of *Ceratitis giffardi*

collected in the fruits of Chrysobalanus on August 2–3, 1912, at Dakar, Senegal. Silvestri later reared specimens from *C. giffardi* and *C. tritea* at Olokomeji, Southern Nigeria, and from *C. giffardi* at Kokoulima, French Guinea. He was also able to rear this parasite at Dakar from pupæ formed by larvæ of *C. giffardi* parasitized experimentally during the period September 6 to 8, 1912. He was unable, however, to arrive at Honolulu with living specimens and it remained for the Fullaway-Bridwell expedition of 1914 successfully to introduce *D. fullawayi* into Hawaii from Olokomeji via Teneriffe, Habana, and the southern United States. Fullaway arrived at Honolulu on October 27, 1914, with 12 female and 19 male specimens. These had multiplied in the laboratory to 419 females and 1,000 males by December 31, and of this number 35 and 160 specimens were liberated during December at Maunawili, Oahu, and Kona, Hawaii, respectively. Although many specimens have been and are still being reared and liberated, this parasite appears to be well established on the Island of Oahu. In the Kona District of Hawaii, however, where it should have become established with greater ease, only two specimens have been reared from larvæ emerging from coffee cherries. These two specimens of *D. fullawayi* on Hawaii were reared by the writers from larvæ collected at Kainaliu on January 15, 1915, and February 13, 1916, or about 1 and 13 months, respectively, after the original liberations at this point.[1]

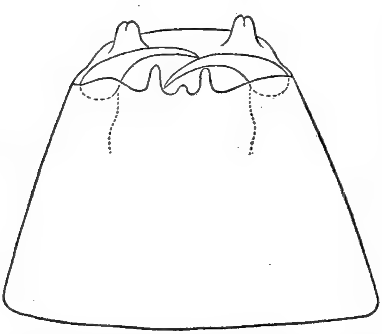

FIG. 23.—*Diachasma fullawayi:* Ventral aspect of head of newly hatched larva; greatest width, 0.3 mm. (Original.)

On Oahu, particularly in and about Honolulu, this parasite has multiplied with rapidity and was found well established in all parts of the city during September and October, 1915.

DESCRIPTION.

Adult.—The original description of the adult is as follows:

♀. Body ferruginous or ochraceous-ferruginous with the antennæ fulvous brown, the wings hyaline, with the veins fulvous brown and the stigma, in part fulvous-ferruginous, tarsi of the posterior legs slightly brownish. Head somewhat broader than long, densly covered with piliferous points, with the face slightly inflated in the middle to form a carina, antennæ longer than the body, with 44 segments. Eyes small, about twice as long as wide. Mesothoracic scutum with deep converging parapsidal furrows which meet a little before the posterior margin in a deep common pit; from this pit a median furrow proceeds directly forward, at first deep but gradually disappearing on the surface near the middle of the scutum; the entire surface

[1] Examinations made by C. E. Pemberton in Kona during May and June, 1916, found it to be established beyond question.

rather densly and closely hairy; transverse prescutellar sulcus provided with four deep pits, of which the lateral ones are deeper than the median; the scutellum is smooth and rather hairy; slightly crenulate laterally before the prealar pit; metanotum with a small median pit divided by a short carina, crenulate on the sides; propodeum strongly and irregularly foveolate. Front and hind wings with the venation shown in figure [Pl. XXI, fig. 1]. Abdomen with the first segment smooth; ovipositor straight, longer than the abdomen. Length of body, 3.6 mm.; width of thorax, 0.1 mm.; length of antennæ, 5.2 mm.; length of front wing, 3.7 mm.; width of same, 1.37 mm.; length of third pair of legs, 4 mm.; length of ovipositor, 3.5 mm.

♂. Differs from the female in having the wings more or less infuscate.

Larva.—The newly hatched larva is similar to that of *Opius humilis*, as illustrated by figure 20, *a*, *b*, as well as that of *Diachasma tryoni*, but it may be readily distinguished from that of *D. tryoni* by the possession of three instead of two toothlike projections on the anterior margin of the ventral chitinized plate of the head (fig. 23).

Pupa.—The pupa, which is about 3.2 mm. long, is most easily recognized from that of *humilis* and *tryoni* by the length of the ovipositor. (Fig. 24.)

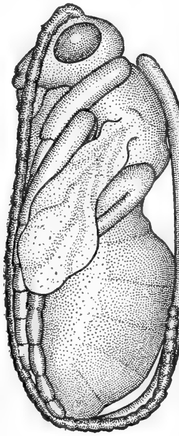

FIG. 24.—*Diachasma, fullawayi:* Lateral view of pupa; normal length, about 4 mm. (Original.)

BIOLOGY OF THE OPIINE PARASITES.

Very little is known regarding the details of the life history of the three opiine parasites introduced into Hawaii. The biology of parasites now attacking *Ceratitis capitata* in Hawaii is at present being made the subject of special investigation by the junior writer. No data on the length of the various stages have been published except by Silvestri and Gurney. Silvestri's statements may be summarized as follows: That adults of *Opius humilis* emerging on April 3, 1913, were still alive on his arrival at Honolulu on May 16, when they deposited eggs from which adults developed within 14 days; that eggs of *Diachasma fullawayi*, at Dakar, Senegal, deposited on September 6 to 8, 1912, developed adults September 21 to 24, and that *D. tryoni* can complete its egg, larval, and pupal development in from 14 to 16 days. The data supplied by Gurney deal with *D. tryoni* only and will be considered later. The information of the writers is not complete and therefore is given as follows in the form of biological notes in anticipation of a more complete publication. It might be added that such data as are presented here were obtained incidental to other work.

Length of adult life.—Adults die in about 48 hours if not fed. When confined in test tubes $1\frac{1}{4}$ inches in diameter and about 8 inches long and fed daily, they live much longer, as indicated by the data in Table XXIV.

TABLE XXIV.—*Longevity records of Opius humilis and Diachasma tryoni*[1] *at Honolulu from November, 1914, to March, 1915.*

Age on date of observation.	Number of specimens dead.				Age on date of observation.	Number of specimens dead.			
	O. humilis.		*D. tryoni.*			*O. humilis.*		*D. tryoni.*	
	♂	♀	♂	♀		♂	♀	♂	♀
24	1	1	......	......	67	1	2	......	......
25	......	......	1	......	68	......	1	......	......
26	1	......	1	......	69	......	2	......	......
28	3	......	2	......	70	......	1	......	......
29	1	......	......	......	71	......	1	......	......
30	3	2	......	......	73	2	2	......	1
32	4	3	......	1	74	2	3	......	......
34	1	......	......	......	75	1	2	......	......
35	1	3	......	......	76	......	2	......	......
37	2	5	1	......	79	......	4	......	......
38	1	......	......	......	80	......	1	......	1
43	3	7	2	3	81	1	......	......	......
45	7	3	......	1	82	1	3	......	......
46	1	......	1	4	83	......	1	......	......
47	2	6	1	......	84	1	7	......	......
49	3	7	......	......	85	......	1	......	......
50	1	3	......	......	87	......	4	......	1
51	1	1	......	1	88	2	3	......	......
52	1	6	1	1	91	......	2	......	......
53	2	3	1	......	94	2	2	......	......
54	1	2	......	......	95	1	1	......	......
55	......	1	......	......	98	......	3	......	......
56	2	8	......	1	100	......	1	......	......
57	......	......	......	2	101	......	1	......	......
58	5	8	......	......	103	......	1	......	......
59	1	5	......	......	104	......	2	......	......
60	......	4	......	......	105	......	2	......	......
62	1	6	......	......	107	......	1	......	......
63	......	3	......	1	111	......	2	......	......
65	3	8	......	1	124	......	2	......	......
66	......	3	......	......	125	......	2	......	1

[1] No record was kept of adults dying during first 23 days after emergence.

Fourteen females of *Opius humilis* lived to be over 100 days old; the last two being 125 days old. One female *Diachasma tryoni* lived to be 125 days old, although this species appears to be more frail and less able to survive captivity. Unfortunately no record was kept of the number of adults of either species dying during the first 23 days after emergence.

Proportion of sexes.—A count of the sexes of 25 lots of *Opius humilis* reared from *C. capitata* developing in various fruits during September and October, 1914, showed 145 specimens to be females, and 141 males.

Mating.—Mating may occur immediately after emergence in all three species, *Opius humilis, Diachasma tryoni,* and *D. fullawayi.* Virgin females may deposit parthenogenetic eggs which, however, develop males only.

Length of life cycle.—There are no satisfactory data on the length of the life cycle under varying climatic conditions. The statement of Silvestri that the egg, larva, and pupa stages may be completed in from 14 to 16 days is a safe estimate for the minimum length required for the development of these stages. Specimens of *O. humilis,* developing from eggs deposited August 21 to 22, 1914,

were already in the pupa stage when examined on August 31, and emerged as adults 13 to 16 days after the eggs were deposited. The temperature during this period ranged between 74° and 85° F., with a mean of about 79° F. In Table XXV are the summaries of emergence from 35 lots of *C. capitata* pupæ secured from various fruits, and these are presented since they demonstrate clearly that which more detailed data will prove further—that *O. humilis* passes through its immature stages more rapidly than either *D. tryoni* or *D. fullawayi*. As the eggs of the parasites are deposited within the well grown larva before it leaves the host fruits, from 1 to 4 days should be added to the duration of the immature stages indicated in Table XXV.

Three *O. humilis* emerged April 3 from *C. capitata* pupæ formed at Honolulu February 2, 1915, placed on Hualalai (temperature range, 31°–70° F.) February 11, taken to Kealakekua March 26, and to Honolulu March 29; i. e., the duration of the immature stages was increased by this combination of cool weather to about 60 days. Many records on file, not included in Table XXV, indicate that detailed data will show more convincingly that *O. humilis* is less affected by cold weather than either *D. tryoni* or *D. fullawayi*.

Dormancy.—There appears to be no tendency for the larvæ of *O. humilis* to pass through a period of dormancy. The larvæ of *D. tryoni* and *D. fullawayi* often apparently suspend activity when they become full grown and remain dormant for several months. Gurney first observed this phenomenon in the development of *tryoni*. *C. capitata* pupæ collected on February 2, 1915, produced adults of *tryoni* normally as indicated by the data in Table XXV, but two individuals emerged on May 5 and 27, respectively, or 92 and 114 days after the pupation of the host. Larvæ of *tryoni* and *fullawayi* in *C. capitata* larvæ in fruits gathered November 27, 1915, were still in the mature larva stage at the end of eight months (July, 1916). Similar data on the duration of other individuals are on file. Mr. J. C. Bridwell has stated to the writers that he has observed this same resting period among the larvæ of an undetermined African opiine, certain adults of which emerged three and four months after the pupation of the host fruit fly.

Instar of larvæ parasitized.—It is generally admitted by those rearing parasites in Hawaii that the adult parasites deposit their eggs, for the most part, in well grown third-instar larvæ while the fruits are still attached to the tree or have fallen to the ground.[1] The data in Table XXVI show a rapid decrease in the percentages of parasitism among larvæ emerging from fruits during each succeeding two or three day interval after the gathering of the host fruit.

[1] A former statement by the writers that the opiines oviposit for the most part in larvæ in fruits still attached to the tree is subject to modification. While oviposition occurs chiefly in coffee cherries attached to the tree, oviposition in kamani nuts occurs largely after the fruits have fallen.

TABLE XXV.—*Data on emergence of opiine parasites from the puparia of the Mediterranean fruit fly.*

Date.	Host and parasite.	Number of host or parasite emerging on the number of days after the formation of the puparium.																																Mean temperature.	Mean relative humidity.
		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	29	33	36	37	39	40	42	43	44	45	47	48	° F.	P. ct.
Dec., 1915 (6 lots)	C. capitata		30	139	1,202	1,982	1,341	969	69	5	1																							73.1	72.3
	O. humilis		1	2	2	4	22	31	15	14	6	1																							
	D. fullawayi				1	1	10	67	90	150	131	78	83	57	36	13	13	4	1	1															
	D. tryoni															1																			
June, 1915 (11 lots)	C. capitata		36	351	686	43	1																											77.7–78.4	65.7–66
	O. humilis		10	44	70	196	243	159	58	35	13	14	6	2																					
	D. tryoni					30	157	274	238	177	106	46	23	6	0	1	3																		
Sept. and Oct., 1915 (7 lots)	C. capitata		3	84	46	15																												77.2–79	66.9–68.1
	O. humilis			13	29	45	20	8	1	0	1	1																							
	D. tryoni				1	9	26	73	94	74	31	16	5	1																					
Dec., 1915, to Jan., 1916 (3 lots)	C. capitata							9	12	1																								73.1–71	72.3–78.5
	O. humilis										4	1	0	0	0	0	1	1																	
	D. fullawayi											3	2	5	1	3	1	1	0	3	0	1	2	1	6	3	1	2	5	6	1	1	1		
Dec., 1915 (3 lots)	C. capitata				35	230	143	23																										73.7	72.3
	O. humilis							3	2																										
	D. fullawayi						3	81	103	198	164	115	60	24	13	4	0	3	0	0	1														
	D. tryoni										1	0	1	1	1																				
Nov., 1915 (5 lots)	C. capitata			3	0	55	37	20	3																									74.6	70.5
	O. humilis					2	34	52	93	55	30	42	19	4	31	22	1																		
	D. tryoni										2	7	8	2	2	1																			

Table XXVI.—*Percentage of parasitism among larvæ of the Mediterranean fruit fly emerging during various periods after the gathering of the host fruit (coffee).*

Locality.	Date of collection of fruit.	Date of larval emergence.	Number of pupæ yielding adults or parasites.	Percentage of parasitism.			
				Opius humilis.	Diachasma tryoni.	Diachasma fullawayi.	Total.
1752 Luso Street, Honolulu.	Oct. 21,—	Oct. 21–23	37	78.4	0	16.2	94.6
		Oct. 23–25	34	64.7	0	15	79.7
		Oct. 25–27	52	20.0	0	5.4	25.4
Booth Estate, Pauoa Valley.	Dec. 8, 1915	Dec. 8–10	256	0	0.4	92.1	92.5
		Dec. 10–13	338	0.3	.6	78.1	79
		Dec. 13–16	609	.6	.1	43.8	44.5
		Dec. 16–18	258	0	0	12.8	12.8
		Dec. 18–20	76	0	0	6.6	6.6
Kealakekua, Kona district.	Dec. 1, 1915	Dec. 1–2	5	40	60	0	100
		Dec. 2–3	15	86.7	13.3	0	100
		Dec. 3–4	21	71.4	23.8	0	95.2
		Dec. 4–5	33	66.6	21.2	0	87.8
		Dec. 5–6	46	54.3	13	0	67.3
Kainaliu, Kona district	June 18, 1915	June 18–19	46	63	30.4	0	93.4
		June 19–20	65	50.7	41.5	0	92.2
		June 20–21	107	56	32.7	0	88.7
Kahaloa, Kona district	Oct. 30, 1914	Oct. 30–Nov. 3.	41	80.4	2.2	0	82.6
		Nov. 3–6	240	23.3	0.4	0	23.7
		Nov. 6–9	125	3.7	0	0	3.7
		Nov. 9–11	64	0	0	0	0
Hookena, Kona district	Oct. 31, 1914	Oct. 31–Nov. 3.	52	16.7	40.7	0	57.4
		Nov. 3–6	36	17	19	0	36
		Nov. 6–9	86	1.2	0	0	1.2
		Nov. 9–11	79	0	0	0	0

Resistance to cold-storage temperatures.—Indications are that *Opius humilis* can withstand greater cold for longer periods than can its host. Thus 5 *O. humilis* emerged from 2,500 *C. capitata* pupæ after they had been refrigerated for 9 days at about 26° F. Four lots of 1,200 pupæ refrigerated at the same temperature for 5, 6, 7, and 8 days yielded on removal to normal temperatures 30, 32, 8, and 4 Opius. No adult *C. capitata* emerged from those pupæ refrigerated from 5 to 9 days, but from 1,300 pupæ, refrigerated at about 26° F. for a period of 4 days, 3 adults emerged along with 40 *O. humilis.*

No adult *C. capitata* emerged from two lots of 1,900 and 4,500 pupæ refrigerated for 9 and 10 days, respectively, at 32° F., but 7 and 13, respectively, of *O. humilis* emerged. From 1,228 pupæ refrigerated for 18 days at 34° to 36° F. there emerged no adult *C. capitata* but 2 *O. humilis.*

REARING PARASITES.

In rearing parasites the writers have followed, in the main, the methods employed by the Hawaiian Board of Agriculture and Forestry as developed by Messrs. Silvestri, Fullaway, and Bridwell. The board failed to rear the opiine parasites successfully until Mr. J. C. Bridwell, then assistant superintendent of entomology, altered

the procedure so that the parasites were given an opportunity to oviposit in the larvæ within host fruits under more normal conditions. The methods previously used permitted much moisture to gather on the sides of the glass jars in which the host fruits and parasites were placed. The method now recommended by Mr. Bridwell consists in the use of two ordinary nursery flats, the boxes being 16 by 12 by 3 inches. Into one of these is placed a layer of dry sand and a wire container so arranged that it will hold the infested host fruits exposed within it clear of the sand. The second tray, the bottom of which has been replaced by fine-mesh copper wire, is used as a cover and is made sufficiently small so that it can be inverted and thrust down into the tray containing the sand and fruits as soon as vials containing the adult parasites have been unstoppered and placed upon the fruits. By pressing the edges of the covering tray well into the sand the adult parasites are prevented from escaping and ants are, temporarily at least, prevented from interfering with the experiment. When the covering tray is in place, the wire-screen top is not far from the exposed fruits; hence the parasites are forced to confine their activities where they net the best results. The Bridwell method has not only made it possible to rear large numbers of opiines quickly and without skilled labor but is largely responsible for the success of the Fullaway-Bridwell parasite expedition to Africa.

The writers have been able to rear both sexes of the opiine parasites in large numbers very easily since the summer of 1914 by merely placing in test tubes about 2 inches in diameter a number of infested host fruits and parasites. This method requires greater care and produces much sweating of the sides of the containers, but parasitic material of both sexes can be very quickly secured for experimental work, and the investigator has the advantage of being able to observe the activities of the adult parasites. The objectionable feature of excessive moisture was overcome by the use, in the summer of 1914, of a wooden box, the top and bottom of which was of fine-mesh copper wire which contained a sliding shelf made of coarse-mesh wire supported midway between the top and bottom of the box and which could be easily removed through one end of the box which was hinged. This device possessed the advantage, demonstrated by Bridwell, in that it prevented accumulations of excessive moisture and confined the parasites closely to their hosts, but was not so well adapted to the purposes of parasite work since the host larvæ which pupated on the bottom of the box could not be so readily secured. After the host larvæ have emerged from the exposed fruits the pupæ may be easily sifted from the sand beneath the fruits and held in glass jars until the adult parasites have emerged.

It was not necessary to expose adult opiine parasites to strong sunlight for a few minutes each day to hasten mating, as recommended

by Bridwell, and both sexes were obtained within the laboratory without this precaution, possibly owing to the fact that the laboratories were remarkably well lighted.

Cannibalism.—Although thousands of adults representing all three of these opiine parasites have been reared during the past two years, not more than a single individual has been reared from one fruit-fly puparium. Larvæ of the Mediterranean fruit fly within coffee cherries which had been exposed to the attack of *Diachasma fullawayi* during January, 1916, were found to have been attacked in several places, and examination made of the body contents of the parasitized fruit-fly larvæ proved that as many as 8 eggs had been deposited in certain instances. It seems very probable, therefore, that in the field, under normal conditions, adult parasites do not discriminate against larvæ already parasitized when seeking a host and that due to an excessive number of parasitic larvæ within a single host a certain amount of cannibalism occurs. Cannibalism among opiine parasites was first observed by the senior writer while examining the body contents of larvæ parasitized by *Diachasma fullawayi* as previously mentioned. A newly hatched larva was observed vigorously and effectively to attack a second larva of the first instar with its large mandibles. Later examination of large numbers of fruit-fly larvæ by the junior writer have proved conclusively (1) that the last opiine parasite to hatch within a host first kills all other parasitic larvæ within the same host; (2) that the newly hatched larva is more capable of vigorous attack than one which has become engorged; and (3) that it may attack not only larvæ of another species but those of its own as well. As many as eight dead and one living first-instar larvæ have been found in a single host.

STRUGGLE FOR SUPREMACY AMONG PARASITES.

The parasites of *Ceratitis capitata* have been introduced too recently into Hawaii to warrant conclusive statements regarding the outcome of the struggle for supremacy which is clearly taking place. *Opius humilis* has an advantage among the opiines of being more hardy and of being able to pass through the immature stages more rapidly, and it is somewhat less affected by cool weather, whereas *Diachasma tryoni* and *D. fullawayi* have the advantage of possessing much longer ovipositors and are consequently better equipped to reach their host larvæ through the tissues of infested fruits. The more rapid development of the egg and larva stages of *Opius humilis* is, however, not in its favor when it is forced to compete within the same host with either *Diachasma tryoni* or *D. fullawayi*, owing to the cannibalistic habits of the newly hatched opiine larva, which impel it to seek out and destroy larvæ that have hatched earlier and already commenced feeding within the same host.

While it will probably take a number of years to determine just what advantage the longer ovipositor will afford *Diachasma tryoni* and *D. fullawayi* over *Opius humilis*, the data in Table XXVII clearly demonstrate the value of the cannibalistic habits of the newly hatched larva to the more slowly developing species.

TABLE XXVII.—*Percentage of parasitism by Opius humilis and Diachasma tryoni in larvæ of Ceratitis capitata in Kona, Hawaii.*

Locality.	Dates of larval emergence, 1915.	Percentage of parasitism.		
		Opius humilis.	Diachasma tryoni.	Total.
Kainaliu	Jan. 15–16	97.6	0.8	98.4
	Jan. 16–18	92.7	.8	93.5
	Feb. 6–8	85.3	9.3	94.6
	Mar. 15–18	92	0	92.0
	Mar. 18–19	85.1	0	85.1
	June 18–19	63	30.4	93.4
	June 19–20	50.7	41.5	92.2
	June 20–21	56	32.7	88.7
Honaunau	Jan. 19–20	82.8	3.4	86.2
	Feb. 9–10	64.2	4.7	68.9
	Mar. 19–24	73.9	.6	74.5
Honaunau	Mar. 24–26	81.2	0	81.2
	June 17–18	46.7	40.3	87.0
	June 19–20	40	49.6	89.6
	Sept. 19–20	13.9	65.1	79.0
	Sept. 20–21	10.6	69.6	80.2
Kealakekua	Feb. 6–8	79	0	79
	June 16–18	31.4	23.9	55.3
	Sept. 18–19	17.6	67.6	85.2
	Sept. 19–20	23	56.4	79.4
	Sept. 20–21	37.3	48.3	85.6

Data previously published by the writers have shown that *O. humilis* itself is capable of killing as high as 80 to 100 per cent of the larvæ of *Ceratitis capitata* developing in coffee cherries in the Kona district of Hawaii. The data secured during 1915 showed that there was a decided increase in the percentage of parasitism caused by *D. tryoni*. This increase, however, as shown by the data of Table XXVII, was largely at the expense of *O. humilis*, since the total percentage of parasitism was not in excess of that which *O. humilis* could have brought about by its own efforts. In the absence of large amounts of data necessary to the definite estabiishment of this point, the writers are of the opinion that similar fluctuations in the relative importance of *humilis* and *tryoni* are likely to occur each year unless *fullawayi* becomes thoroughly established, in which case it is likely to supplant *tryoni*. The gradual increase in the abundance of *tryoni* during the year is accounted for by the gradual removal, as the summer months approach, of the restrictions upon parasite development which cause a greater relative acceleration in the development of *tryoni* than in the case of *humilis*. This, aided by cannibalism, explains the ascendancy of *tryoni* during the summer and of *humilis* during the colder winter months. It would appear that *C. capitata* in the coffee sections of Hawaii would have been quite as effectively controlled had no opiine other than *humilis* been introduced.

It is doubtful if the same fluctuation in the relative abundance of *tryoni* and *fullawayi* on the one hand and of *humilis* on the other

will take place in the warmer littoral regions about Honolulu where checks due to cool weather are not so effective as in Kona. A study of the data in Table XXVIII shows that *Diachasma fullawayi* gives promise of being a most efficient parasite, particularly of fruit-fly larvæ in coffee cherries, since almost unaided it produced a mortality, in one instance, of 92.5 per cent of 256 larvæ emerging from coffee cherries in Honolulu on December 8 to 10, 1915, which date was about one year after it had been liberated.

Data more recently secured by the junior writer indicate that instead of supplementing the work of the opiines, *Tetrastichus giffardianus* will prove a competitor, as its larvæ appear to be able to hold their own against opiine larvæ within the same host, usually causing their death. While both *Tetrastichus giffardianus* and *Pachycrepoideus dubius* (Pl. XX, fig. 2) have been reared during 1915 and 1916, neither is sufficiently abundant to become an effective factor in control at present.

GENERAL EFFECTIVENESS OF PARASITE CONTROL.

Only a beginning has been made in determining the effectiveness of parasites as a control factor in the Hawaiian Islands, yet the rapidity of establishment and increase of the parasites has been very gratifying. The data already published recording the percentage of parasitism secured during 1914 and 1915, together with the additional data of Table XXVIII, indicate, however, that while parasitism in such fruits as the coffee cherry is remarkably high, in fruits with a thicker pulp, such as the orange, it is very low. The data of Table XXVIII have been chosen particularly as they demonstrate that immense numbers of adult *Ceratitis capitata* are developed in spite of the excellent work of the parasites in certain host fruits. Since adult fruit flies can live many months and oviposit quite regularly as shown by the biological data, they have been able, with the aid of the unprecedented variety and abundance of host fruits growing in Hawaii, thus far to keep such an ascendency over their parasites that they cause the infestation of practically all fruits which are permitted to ripen. It would appear that unless effective pupal or egg parasites are introduced, or unless care is given to the elimination of host fruits which more thoroughly protect the larvæ from parasite attack and to the planting of fruits in which the fly is heavily parasitized, little of practical value can be expected from the parasites discussed in this paper either in rendering host fruits entirely free from attack or in raising the present quarantine against Hawaiian fruits. In Kona, Hawaii, where the percentage of parasites in coffee cherries has been phenomenally high for two years, it has been high enough merely to render an occasional fruit free from attack.[1] The control

[1] The statement of W. M. Giffard that the infestation of coffee cherries during 1914 was at least 50 per cent less than during the previous year, and that in some fields it was difficult to find any great infestation, should be interpreted as referring to the cherries which, although nearly all infested, were infested so late in development that their pulp was little affected when the fruits were picked.

executed by parasites has, however, effected a benefit to coffee growers which has probably already repaid the Territory of Hawaii for all money expended in parasite introduction, since the parasites, by greatly reducing the abundance of adult flies, have postponed the infestation of the pulp until the cherries have become quite well ripened, at which stage little loss to the coffee results.[1]

TABLE XXVIII.—*Percentage of parasitism among larvæ of the Mediterranean fruit fly developing in host fruits during November, 1915–February, 1916.*[2]

Locality.	Host fruit.	Date of larval emergence.	Total number pupæ yielding adults or parasites.	Percentage of parasitism.				
				Opius humilis.	Diachasma tryoni.	Diachasma fullawayi.	Tetrastichus: giffardianus.	Total.
Hilo, Hawaii:								
Pitman Street	Coffee	Nov. 18–22, 1915	11	0.0	0.0	45.4	.....	45.4
Do	Wing kamani	Nov. 20–25, 1915	16	18.8	0	0	0	18.8
Hilo Hotel	Coffee	Nov. 19–22, 1915	5	0	0	60	0	60.0
Five Miles	do	Nov. 18–22, 1915	49	12.2	0	0.0	0	12.2
Boarding School	do	Nov. 20–29, 1915	90	1.1	0	2.2	0	3.3
Kona, Hawaii:								
Kealakekua	do	Dec. 1–5, 1915	77	71.4	22.1	0	0	93.5
Kainaliu	do	{Dec. 3–4, 1915	64	68.7	28.1	0	0	96.8
		{Dec. 4–6, 1915	119	63.9	28.9	0	0	92.8
Honaunau	do	Dec. 2–3, 1915	40	35	57.5	0	0	92.5
Honolulu:								
1560 Beretania Street	Loquat	Dec. 15–20, 1915	6	16.6	0	0	0	16.6
Do	do	Dec. 21–24, 1915	10	40	0	0	0	40
Do	do	Jan. 3–7, 1916	40	5	5	5	0	15
Waikiki	Ball kamani	Dec. 20–27, 1915	302	0	0	0	0	0
Ohua Lane	do	Dec. 22–31, 1915	75	0	0	0	0	0
Ainahau	do	Dec. 29, Jan. 1, 1916	186	0	0	0	.5	.5
Ohua Lane	do	Jan. 4–14, 1916	430	.5	0	.2	.3	1.0
Queens Hospital	C. oliviforme	Jan. 25, Feb. 2, 1916	297	2.6	2.0	2.6	0	7.2
Do	do	Jan. 27, Feb. 4, 1916	818	3.6	.6	.7	0	4.9
Do	do	Jan. 29, Feb. 9, 1916	1,954	2.4	.2	.5	0	3.1
Do	do	Feb. 4–18, 1916	870	1.4	0	.5	0	1.9
Do	M. elengi	Jan. 29–Feb. 9, 1916	1,543	.3	0	.1	0	.4
Do	do	Feb. 4–18, 1916	1,194	.5	0	0	0	.5
Do	do	Feb. 7–18, 1916	1,998	.1	0	0	0	.1
1814 Ahuula Street	Bunchosia	Nov. 24–29, 1915	45	31.1	0	0	0	31.1
Punahou Street	Chinese orange	Jan. 1–10, 1916	321	.6	.3	.3	0	1.2
Wilder and Thurston Streets.	do	Dec. 17–22, 1915	14	21.4	0	7.2	0	28.6
Do	do	Dec. 22–31, 1915	286	2.1	0	0	0	2.1
Wilder and Pensacola Streets.	do	Dec. 22–27, 1915	45	15.5	0	0	0	15.5
Upper Pauoa Valley	do	{Jan. 17–20, 1916	162	11.7	5.6	0	0	17.3
		{Jan. 20–24, 1916	817	1.2	.7	0	0	1.9
Wilder and Keeamaku Streets.	do	Dec. 17–20, 1915	143	7	0	0	0	7
St. Mary Mission	do	Dec. 16–24, 1915	316	1.5	0	.3	0	1.8
1436 Young Street	do	Dec. 13–16, 1915	5	40	0	0	0	40
Enos Lane	do	Dec. 9–20, 1915	182	3.9	0	5.5	0	9.4
Makiki and Lunalilo Streets	do	Dec. 8–13, 1915	59	0	0	3.4	1.7	5.1
Lunalilo Home	do	{Nov. 26–29, 1915	4	50	0	25	0	75
		{Nov. 29, Dec. 1, 1915.	43	14	0	7	0	21
		{Dec. 1–6, 1915	292	.7	.3	0	0	1.0
1571 Makiki Street	Coffee	Nov. 29, Dec. 1, 1915.	54	5.5	0	85.2	0	90.7
1752 Luso Street	do	Dec. 8–13, 1915	415	1.7	.5	77.3	0	79.5
Booth, Pauoa Valley	do	Dec. 8–10, 1915	256	0	.4	92.1	0	92.5
Do	do	Dec. 13–16, 1915	611	.6	.1	43.7	.3	44.7
Upper Manoa Valley	do	Dec. 9–13, 1915	12	0	0	83.3	0	83.3
2030 Nuuanu Street	do	Dec. 11–13, 1915	22	4.6	0	81.8	0	86.4
Pauoa Valley	do	Jan. 1–3, 1916	9	11.1	0	88.9	0	100.0

[1] The losses to coffee growers due to excessive fruit-fly attack have been discussed on p. 34.

[2] Braces are used only when denoting the same lot of fruit.

While it seems evident that the favored host fruits of *C. capitata* will always be well infested if present cultural conditions persist, it is hoped that the value of the parasites may be sufficiently enhanced to free from attack such fruits as the avocado pear, which at present is infested just at the stage at which it becomes fit for harvesting.

The general effectiveness of parasite control will be increased with the discovery and introduction of a suitable egg parasite.

ARTIFICIAL CONTROL.

The only method employed at the present time in Hawaii satisfactorily to protect fruits from attack of the Mediterranean fruit fly is the covering of the fruits while they are still too green to be affected. The value of the use of cold storage as a method of rendering fruits already harvested free from danger as carriers of the pest has been demonstrated, but cold storage, of course, can have no bearing on the activities of the fruit fly in the orchard. No satisfactory substance has yet been discovered for trapping adult females, and the killing of adults of both sexes by poison sprays is not a feasible method of control in Hawaii under present cultural conditions any more than is the destruction of the immature stages by the burial, submergence, burning, or boiling of the infested host fruits. The exceptional conditions found in Hawaii make impracticable at the present time the application of any of these field methods of control, except that of covering the young fruit, notwithstanding the fact that the value of these control measures when they can be consistently, intelligently, and universally applied, has been demonstrated.

PROTECTIVE COVERINGS.

The only certain method now known of protecting fruits from attack by the Mediterranean fruit fly is to cover them when still quite young with some type of covering through which the female will not deposit eggs. During 1898 Fuller reports that about 22,000 running yards of mosquito netting were imported into South Africa for use in covering trees to protect the fruit from fruit-fly attack. The cloth was sewed into bags sufficiently large to be slipped over the trees and tied about the trunk. This method has been employed by the writers in protecting ripening peaches. Care must be taken, in Hawaii at least, to place the bags over the trees when the fruits are very small or early infestations will have already occurred which, after the coverings have been placed, will produce generations of adults that will result in the infestation of the entire crop beneath the covering.

Covering the entire tree is too expensive to be followed out on a large scale, and entirely impractical with large trees or in windy areas. Protecting fruits with individual coverings made of cloth or paper is more popular in Hawaii. Fruits inclosed in paper bags are well

and cheaply protected. Coverings of cheese-cloth are often matted against the fruit by rains, thus making it possible for the female fly to oviposit in the fruit. The practice of covering mangoes with paper bags will afford protection to certain scale insects and permit them to develop and ruin the fruit.

Frequently all the fruits on a tree may be seen inclosed in paper bags. While this method of covering each fruit gives protection from the fruit fly, it involves much labor and patience and its practicability can only be determined by the value placed upon the fruit by the owner. So severe is fruit-fly attack in Hawaii that this method, in some one of its many modified forms, is the only remedy if fruits are to be brought to maturity uninfested.

CLEAN CULTURE.

Clean culture in its broadest sense includes not only the detection, collection, and destruction of all infested fruits but also the elimination of useless or unnecessary host trees or shrubs. In some one or all of its phases it has been recommended and practiced in every country where the fruit fly is a pest, and in each one of these countries the lethargy displayed by a majority of the people, no matter how much they have regretted their losses, has rendered the clean cultural methods inefficient. The effectiveness of clean culture depends upon many factors, of which cooperation among property owners, honesty on the part of inspectors, climatic and host relationships, the topography of the country, and a thorough knowledge of host fruits on the part of the director are the most important. Clean culture in the Bermudas, where conditions are exceptionally favorable for stamping out the pest, was rendered less effective, up to 1914, because there was lacking a thorough knowledge of the complete list of host fruits subject to infestation. The fruit fly has been stamped out at Blenheim, Napiers, and Davenport, New Zealand, and at Launceston, Tasmania, by the application of such clean cultural methods as the destruction of the fruits and the treatment of the soil beneath the trees with kerosene immediately after the discovery of the pest. The only other recorded instance of success attained as a direct result of clean cultural methods is that of the orange growers of the Blackall Range, in Queensland, Australia. These growers held a council and voted to grub out every kind of fruit tree except the orange, which was their staple crop. As a result of this drastic remedy the fly had nothing in which to breed during nine months of the year in this section, and therefore ceased to be a pest.

The clean-culture campaign instituted by the Hawaiian Board of Agriculture during the fall of 1911 and continued by the Federal Bureau of Entomology from October, 1912, until April, 1914, was unsuccessful from its inception, since it did not protect the fruit

from attack. The main factors contributing to failure were lack of adequate police powers, adverse host and climatic conditions, and the absence, at that time, of any commercially grown orchard crop worth protecting. The impracticability of control by the clean-culture method was recognized by Mr. C. L. Marlatt, who, as a Federal representative immediately in charge of the Hawaiian investigations, was in personal touch with the problem during September, 1912. It was felt, however, that inadequate as this method had proved itself after a nine months' trial from the standpoint of alleviating the Hawaiian situation, it seemed still to offer the best-known way of safeguarding the interests of mainland fruit growers. Therefore, for the purpose of lessening the opportunities of spread to the coast, the destruction of fruits which could be carried on board ships was continued. It was not until after representatives of California,[1] Hawaii,[2] and the Federal bureau had reached the conclusion that no benefit was accruing either to the local or to the mainland interests that the campaign was discontinued.

It is doubtful if ever a clean-culture campaign against the Mediterranean fruit fly was organized so efficiently or on so large a scale as that organized by Mr. W. M. Giffard of the Hawaiian Board, to include the city of Honolulu. That this method should prove a failure under Hawaiian conditions is no reflection upon the ability of those in charge of the work. Inspectors were prohibited from gathering and destroying fruits unless they could first prove to the satisfaction of the property holder that each fruit was infested, and this restriction upon the activities of the inspectors naturally led to numerous difficulties, particularly with the poorer and uneducated classes who often exerted every effort to save their fruit. This restriction also prevented a systematic gathering of all host fruits within a given area, but necessitated many examinations for the removal, on ripening, of the fruits of each individual tree. As fruits ripen rapidly in the semitropics, it proved a physical impossibility to arrange visits by the inspectors frequently enough to prevent infested fruits from falling to the ground.

The data of Tables III to V illustrate the immense number of host trees and shrubs available for infestation in Honolulu, and the ease with which the fruit fly, uncurbed by climatic conditions, may find fruit for oviposition during any day of the year. A glance at Plates IV, VI, XII, and XIX will convince one of the absurdity of endeavoring to remove all the fruits from many of the huge host trees of the islands. The writers know of many winged kamani trees, beneath which infested nuts may be gathered each week of the year, so tall

[1] Report of Investigation of the Fruit-fly situation in the Territory of Hawaii, F. Maskew. Monthly Bul. Cal. St. Com. Hort., v. 3, 1914, p. 227-238.

[2] W. M. Giffard, Letter of Transmittal to Bulletin No. 3, Haw. Bd. Agr. and For., 1914, p. 7.

and brittle that to remove the fruits before they ripen would be impossible. To this example might be added many others in which the removal of ripening fruit would be equally impracticable.

That the campaign was successful in eliminating the bulk of the fruit ripening in Honolulu during the greater part of the year is evidenced by the inability of the Hawaiian Board to obtain any large amount for their experimental work with parasites during the period the campaign was in progress. Excepting May, June, and early July, it was not an impossibility to gather the bulk of fruits ripening in Honolulu, but during these three months tons of ripening mangoes, falling continuously, presented a situation that could not be successfully combated. (See Pls. XII and XIII.) While tons of mangoes were carried daily to the incinerator or the city dumps, except from the standpoint of city sanitation nothing of value was accomplished.

Notwithstanding the fact that the bulk of the ripening and infested fruits were collected and fruit-fly conditions were unquestionably improved from the standpoint of the numerical abundance of adult flies, the important fact remains that the number of fruit flies that succeeded in reaching maturity was sufficiently large to infest practically every fruit ripening within the city. Kerosene traps placed throughout one of the cleanest sections of the city captured large numbers of flies as proved by recorded data on file both with the Hawaiian Board and this bureau. (See Table XXI, p. 76.)

So far as the writers know, there is no way in which clean culture can be made effective in Hawaii under present conditions. There are no impelling incentives. The islands are thoroughly overrun with the fruit fly, and this applies quite as much to the guava scrubs in pastures (Pl. II), on lava flows, and in mountain valleys and ravines as within the city limits. By far the larger proportion of host trees and shrubs are grown more for protection from the semitropic heat and for their ornamental value than for their fruits (Pl. VI). Large numbers of the host fruits are not edible. The destruction of host vegetation is out of the question until it can be proved that some advantage worth while can be gained. To cut down all host trees of Honolulu at the present time would be to remove a large percentage of her prized vegetation without giving her citizens adequate compensation.

ELIMINATION OF HOST TREES.

It has been stated under a discussion of clean-culture methods that the elimination of host trees and shrubs in Hawaii is impracticable at the present time. Should the Mediterranean fruit fly ever become established in California or the Southern States, wherein there is no such wealth of host fruits and where climatic conditions would assist in control, the elimination of host trees other than the orchard cultures to be protected would play a most valuable part in control

measures. Dr. Trabut found that in Algeria the infestation of oranges greatly increased after the introduction of such crops as peaches and persimmons, since these fruits furnished food for the fly during the summer and early fall months, which for the fruit fly had been starvation months previous to the cultivation of these fruits. Aided by these introduced summer crops, the fruit fly was able greatly to increase, so that when the orange crop began to ripen during the fall and winter months, the pest could attack it with increased force. The elimination of a comparatively few host trees, numerically speaking, in Bermuda would mean the elimination of breeding places over considerable areas. The destruction of unnecessary and valueless host trees serves to restrict the breeding ground, as well as to destroy the sequence of ripening hosts so that many adult flies will die while attempting to bridge the ensuing starvation periods, during which no host fruits can be found for oviposition.

SPRAYING.

It has been demonstrated that the Mediterranean fruit fly must feed for about four days after emergence in the warmer months before the females are capable of ovipositing in fruits. This feeding period may be extended to 10 days during winter in littoral Hawaii. Although the interval between emergence and oviposition is short, it offers the best opportunity to kill this pest by means of poisoned baits or sprays. Mally, in South Africa, first appreciated the vulnerability of this point in the life cycle and developed and demonstrated the value of poison sprays as a factor in the control of the Mediterranean fruit fly. Berlese, in Italy, however, working quite as independently, carried out similar experiments to check the olive fly (*Dacus oleae*). Equal credit is due Mally and Berlese for the use of poison sprays in combating fruit flies.

The results of the experimental work of Mally during 1904–5 and of Dewar during 1915 were not successful, although encouraging. The later work of Mally during 1908–9 proved conclusively the value of poison sprays under South African conditions. Mally states that "a severe outbreak of the pest in a commercial peach orchard was brought to a sudden and practically complete halt, and the fruit maturing later was marked under the guarantee of freedom from maggots," while the infestation among fruits on check trees increased until practically all fruits had become infested. These experiments lead Mally to state that *Ceratitis capitata* can be controlled most perfectly under orchard conditions by means of a light sprinkling of a poisoned sweet over the trees just before or during the ripening period of the fruit. In 1912 Lounsbury demonstrated the applicability of the poison spray under town conditions in South Africa during most unfavorable weather conditions, and concluded that if spray-

ing is properly done this remedy is applicable under town conditions, even where the summer rainfall may be heavy.

In Western Australia Newman carried on spraying experiments during a $5\frac{1}{2}$-months period (December 5, 1913, to May 25, 1914) when the fruit fly was most destructive. From the orchard at Crawly Park, in which he experimented, little or no sound fruit, other than grapes, had been picked for several years. The extreme dryness of the Western Australia summer, during which little or no rain or dew falls, affords an especially opportune time for making the best use of poison sprays. Newman estimated the cost of spraying an acre, where an application of one pint of spray was made every 12 to 14 days, to be from $1.50 to $2 per fortnight, and stated that this sum was a mere bagatelle to the loss of fruit during a similar period over a like area. His work convinced Newman that good results will follow the consistent application of poison sprays, particularly when supplemented by the proper destruction of infested fruits.

In the Hawaiian Islands there are no real orchards in which spraying experiments can be conducted under commercial conditions. Severin states that while he captured in 10 kerosene traps, hung among 400 trees, 10,239 flies during a 5-weeks period before starting spraying work, in the following 5 weeks, during which these trees were sprayed about once a week, the same traps caught only 182 flies, and of these 93 were caught during the first 6 days after the first application of spray. Inasmuch as the orchard in question is composed of small citrus trees interplanted with peach and contains a few strawberry-guava, fig, Chinese-orange and rose-apple trees, and is surrounded on one side by wild guava scrub, it is unfortunate that no data were given on the time of the year the spraying was done or on the condition of the host fruits in and about so small an orchard.

The conclusions of Weinland following his spraying experiments conducted during 1912 in dooryards of Honolulu are misleading. He used the data from 7 traps as a basis for his favorable report; had he used the data from 10 other traps in the same series of his experiments which are on file with the Hawaiian Board of Agriculture and Forestry he could have shown that on the whole his experiments were not successful, and that in several instances he caught more flies after spraying than before. The writers have demonstrated from an immense amount of data on the number of flies caught in single traps throughout a given year that even when no spraying is done there may be a sufficient falling off in the numbers of fruit flies captured to mislead one into thinking that the trees had been sprayed.

The only test of poison sprays made by the writers was in an attempt to control the Mediterranean fruit fly under adverse town conditions such as have been described on page 11. The city block in Honolulu bounded by Punahou, Beretania, Wilder, and Makiki Streets was sprayed every 2 or 3 days from July 17 to August 28, 1913. The adjoining blocks to the southeast were held as a check and the number of flies captured in 145 traps in the sprayed area and in 147 traps in the check area constituted the basis for determining the benefits of the poison spray. Knapsack sprayers only were used, and while all trees and shrubs received spray, none were sprayed more than 9 feet above ground. The average number of flies caught daily each week is recorded in Table XXIX.

TABLE XXIX.—*Number of Mediterranean fruit flies caught in 145 and 147 traps hung in sprayed and unsprayed areas, respectively; spraying begun July 17, ended Aug. 28, 1913.*

Date.	Average number of flies caught each day during week ending.		Date.	Average number of flies caught each day during week ending.	
	Sprayed area.	Unsprayed area.		Sprayed area.	Unsprayed area.
July 5	1,191	769.2	Aug. 23	215.8	561.8
July 12	881.4	722.5	Aug. 30	111.1	439
July 19	936	769.4	Sept. 6	102.7	315.5
July 26	541.2	727.2	Sept. 13	71.2	219.1
Aug. 2	472.5	904.5	Sept. 20	76.5	151.8
Aug. 9	383.8	937	Sept. 27	90	141.2
Aug. 16	269.4	762.8			

The data show that the number of flies caught in the sprayed area was greatly reduced by the spraying. The reduction in flies was not great enough, however, to save fruit of any host ripening from becoming badly infested. Similar experiments conducted during May and June, 1914, in an attempt to protect peaches ripening in town dooryards were failures. Of several thousand fruits only three reached maturity uninfested.

The composition of the poisoned-bait spray used against the Mediterranean fruit fly consists of some poison, a sweet substance attractive to the adults, and water. Mally in 1909 used the following formula: Sugar, 3 pounds; arsenate of lead, 4 ounces; water, 5 gallons. He found that from 1 to 1½ pints were sufficient for the average 10-year-old peach or nectarine tree. Lounsbury in his town demonstration work used a spray consisting of 6 pounds brown sugar, 6 ounces arsenate of lead paste, and 8 gallons water. Weinland used a spray of 3½ pounds lead arsenate paste, 10 pounds brown sugar, 5 gallons plantation molasses, and 50 gallons water. Severin used the Mally formula, but increased the lead arsenate from 3 to 5 ounces. The writers used the formula of Weinland.

The writers believe that poisoned-bait sprays if carefully applied under such commercial conditions as exist in California and Florida would prove successful. Their observations indicate that honeybees are in no way affected by these sprays. It is doubtful, however, if poisoned-bait sprays will ever be practical under present-day cultural conditions in Hawaii, where no fruit crop is grown commercially, where the majority of host fruits are either inedible or not worth the cost of spraying, and where sources of reinfestation from without are so great. The entire subject of control by spraying with poisoned baits is still open for investigation under varying conditions.

COLD STORAGE.

A discussion of the use to which cold-storage temperatures may be put as an aid in offsetting the disastrous results of attack by the Mediterranean fruit fly was published by the writers[1] in 1916. The experimental work was undertaken primarily with the hope that it would be an aid in solving the discouraging problems of local horticulturists. But whatever its value in this direction, it now appears that the results may be of much greater commercial importance in defining the conditions under which cold-storage temperatures will kill the fruit fly in stored fruits, thus rendering them free from danger as transporters of this pest from one country to another, or even from one infested district to another. It seems reasonable to conclude that sooner or later the certification of properly refrigerated fruit will be practicable. When an association of fruit growers or a community awakens to a realization of the financial value of the cold-storage treatment there is reason to believe it will result in the operation of central refrigeration plants under the supervision of officials whose guarantee will insure that all fruits sent out from the plant are absolutely free from danger as carriers of the Mediterranean fruit fly.

Experimental work in Australia, as an example, has shown that such perishable fruits as peaches and Japanese plums can be placed on the European markets in good condition if sent in cold storage, and such exports have been encouraged under Government guarantees. While cold storage can never lessen the damage already done by larvæ within fruits offered for sale or shipment, and in no way deals with the root of the trouble, as a palliative, guarding fruits against further attack while in storage or transit, it may become of inestimable value. Fruits, such as apples, that contain freshly-laid eggs or very young larvæ may be placed upon the market, provided further fruit-fly development is checked by cold storage.

For the details of the effect of cold-storage temperatures upon the eggs, larvæ, and pupæ of the Mediterranean fruit fly, as well as for

[1] Back, E. A., and Pemberton, C. E., Effect of cold-storage temperatures upon the Mediterranean fruit fly. Jour. Agr. Research, v. 5, no. 15, 1916, p. 657–666; Back, E. A., and Pemberton, C. E., Effect of cold-storage temperatures upon the pupæ of the Mediterranean fruit fly. Jour. Agr. Research, v. 6, no. 7, 1916, p. 251–260.

historical facts dealing with the use of such temperatures, one should consult the two articles to which reference has been made. Fruits of almost any variety commonly placed in cold storage are held at temperatures varying from 32° to 45° F., with preference shown to a range of 32° to 36° F. By way of general summary of many experiments, including observations upon over 26,000 eggs, 60,000 larvæ, and 173,000 pupæ to determine the effect of such temperatures as 32°, 32° to 33°, 33° to 34°, 34° to 36°, 36°, 36° to 40°, 38° to 40°, and 40° to 45°, it may be said that no stage of the Mediterranean fruit fly can survive refrigeration for seven weeks at 40° to 45° F.; for three weeks at 33° to 40° F., or for two weeks at 32° to 33° F.

EFFECT OF FREEZING TEMPERATURES UPON THE EGG, LARVA, AND PUPA.

The only freezing temperatures available in Hawaii for experimental work with eggs, larvæ, and pupæ were those found in cold-storage plants maintaining rooms for the refrigeration of fish and meat. The temperature of these rooms ranged between 21° and 30° F. though averaging close to 26° F. Out-of-door freezing temperatures have been experienced by the writers on the Island of Hawaii at an elevation of over 8,000 feet, but lasted only for a few hours at a time and occurred on mountain slopes not easily accessible.

THE EGG.

Apples in which fruit-fly eggs had been deposited on November 3, 1914, were placed in cold storage at a temperature varying from 24° to 30° F. Fruit was removed daily for 10 consecutive days and observations made on a total of 5,434 eggs contained within them. No eggs survived more than 7 days of refrigeration at this temperature. Of 507 eggs subjected to 25° F. for one day 414 hatched on removal to normal temperature; 275 of 308 eggs subjected to 24° to 25° F. for 2 days hatched after removal; 588 of 741 eggs hatched on removal after refrigeration for 3 days at 24° to 26° F.; 430 of 748, 65 of 384, 7 of 534, and 1 of 255 eggs hatched on removal after refrigeration at 24° to 30° F. for 4, 5, 6, and 7 days, respectively. All of 606, 624, and 727 eggs removed to normal temperature after 8, 9, and 9 days of similar refrigeration were dead.

In a second experiment carried out during July, 1913, peaches containing eggs were picked promiscuously in the field, and placed in storage at 26° to 30° F. The results were similar to those mentioned above, as 42 of 178, 7 of 10, and 20 of 145 eggs hatched on removal, after refrigeration for 1, 2, and 6 days, respectively; 57, 148, 82, 134, and 14 eggs refrigerated for 7, 9, 10, 11, and 12 days were dead on removal from storage.

THE LARVA.

First-instar larvæ.—A total of 2,116 first-instar larvæ were placed in cold storage at 21° to 28° F. None survived more than 5 days of refrigeration, and the following observations were recorded: 62 of 248 larvæ in refrigeration for 5 days were found living on examination after removal to normal temperature; 297 of 340 survived one day of refrigeration at 22° to 23° F.; 239 of 275 survived two days of refrigeration at 21° to 23° F.; 110 of 243, and 44 of 240 survived refrigeration at 21° to 28° F. for 3 and 4 days, respectively; 264, 132, 213, and 141 larvæ refrigerated for 6, 7, 8, and 9 days, respectively, were dead on removal from storage.

In a second room, the temperature of which ranged from 26° to 30° F., infested peaches were placed. An examination of the contained larvæ after refrigeration gave results similar to those above; 21, 9, 9, and 19 larvæ were found dead after 5, 6, 9, and 12 days of refrigeration, and 336 removed after refrigeration from 13 to 15 days were dead.

Second-instar larvæ.—A total of 3,216 second-instar larvæ were subjected to freezing temperatures with the following results: 367 of 377, 77 of 123, and 9 of 195 larvæ were found living on removal to normal temperatures after refrigeration for 1, 2, and 3 days, respectively, at 21° to 29° F. An average of 361 larvæ removed after refrigeration 4, 5, 6, 7, 8, 9, and 10 days were dead. No living larvæ were found after the third day of refrigeration.

Third-instar larvæ.—Of a total of 6,774 third-instar larvæ in kamani nuts (*Terminalia catappa*) subjected to freezing temperatures ranging between 22° and 27° F. for 1 to 9 days, 82 of 157 and 4 of 510 larvæ were found alive upon removal after refrigeration at 24° to 27° F. for 1 and 3 days, respectively. Only 3 of 524 were alive on removal after 4 days of refrigeration at 22° to 27° F. An average of 1,221 larvæ removed daily between the fifth and ninth days of refrigeration were dead.

After refrigeration at 26° to 30° F. 114, 7, 1, 12, and 124 larvæ in peaches were found dead on removal after 5, 6, 9, 12, and 15 days, respectively, of refrigeration. Ten badly infested peaches were removed to the laboratory after 3 days of refrigeration and from two of these there later emerged 1 and 9 full-grown larvæ which pupated normally and produced adults. No adults were reared from 15 peaches removed after 14 days of refrigeration.

Fourteen peaches held in refrigeration 5 days at 26° to 30° F., then successively for 24 hours each at 33° to 38° F. and 40° to 45° F., were removed to the laboratory. A total of 36 third-instar larvæ, found within the fruit, were dead.

THE PUPA.

A total of 21,450 pupæ have been subjected to freezing temperatures varying from 24° to 32° F. and averaging about 26° F. All pupæ were fatally injured before the end of the fourth day of such refrigeration. Three hundred 3-day-old pupæ, 100 2-day-old pupæ, and 200 1-day-old pupæ on removal to normal temperature after 3¾ days of refrigeration at about 26° F. produced 1, 1, and 1 adults, respectively. Under similar conditions only 2 of 100 4-day-old pupæ and 3 of 200 3-day-old pupæ produced adults after 3 days of refrigeration. Each lot of pupæ ranging from 1 to 9 days old and totaling 1,900 individuals yielded from 2 to 22, or a total of 78 adults, after 2 days of refrigeration. Even 1 day of refrigeration at 26° F. proved fatal to a large percentage of pupæ, especially the younger, as evidenced by data in Table XXX covering observations on 1,500 pupæ.

TABLE XXX.—*Effect of 26° F. upon pupal life. Pupæ placed in cold storage Oct. 27, 1914; removed to normal temperature Oct. 28.*

Age of pupæ (days).	Number of pupæ.	Number of adults emerging on—									
		Oct. 30.	Oct. 31.	Nov. 1.	Nov. 2.	Nov. 3.	Nov. 4.	Nov. 5.	Nov. 6.	Nov. 7.	Nov. 8.
9	100	5	18	4							
8	100	1	6	42	10						
7	100			5	15	12					
6	200					45	5				
5	200						9	1			
4	200						5	7			
3	200							14	21		
2	200								7	3	
1	200								13	2	1

During May, 1913, 500, 119, and 331 pupæ of all ages were placed in cold storage, the temperature varying from 22° to 24° F. for 5, 7, and 12 days, respectively. After removal to normal temperature all pupæ were found to be dead. During July, 1913, 2,000 pupæ of various ages were subjected to a temperature varying from 24° to 30° F. and averaging about 26° F. for 3 to 16 days; none yielded adults after removal from storage even after only 3 days of refrigeration. On June 24, 1913, 2,500 pupæ removed from storage after one month of refrigeration at about 26° F. were found dead.

Pupæ held in refrigeration 4 days at 24° to 30° F. were removed to normal temperature after being held 2 successive days at 33° to 38° F. and 40° to 45° F., respectively, but none yielded adults.

TRAPS.

The idea of exposing in infested areas a substance that will attract both sexes of the Mediterranean fruit fly is an excellent one, and may lead to the discovery of some medium which will prove an effective method of control. It was the writers' idea to simulate, in such a substance, the odor emanating from the male *C. capitata*, but the experiments proved unsuccessful. Severin exposed various oils derived from crude petroleum, but found them ineffective. He also used, without satisfactory results, turpentine, coconut oil, citronella, whale and fish oils, vinegar, and vanilla. Hooper in Western Australia experimented with naphtha and turpentine in 1907 without success, and similar results followed the exposure by Gurney in New South Wales of citronella, linseed, salad, whale, neatsfoot, and fish-oils. Howlett, in India, was able to attract males of *Dacus zonatus* and *D. diversus* by exposing citronella oil. Later he believed that he had found the actual substances which are responsible for the attraction of these two species in isoeugenol and methyleugenol. Three traps containing, in the order mentioned, eugenol, methyleugenol, and isoeugenol hung in orange trees in a badly infested area of Honolulu captured in 6 days only 2, 10, and 1 male *C. capitata*, as compared with 77, 153, and 48 males captured in check traps containing kerosene hung within 50 feet of them. These three substances were furnished the writers by Severin, who had received them in turn from Howlett.

Much of the experimental work to which reference has just been made represents but a small amount of that undertaken to determine the effectiveness of traps. It has grown out of the accidental discovery in Australia by a housewife that a coating of kerosene oil, put about a post for the protection of a glass of preserves from ants, was attractive to adult *C. capitata*. This observation led to the heralding, in 1907, of the use of kerosene as a method of control as the "best discovery against the fruit fly in years," and to regulations in Western Australia requiring fruit growers to place from one to two traps in each fruit tree. It is natural that entomologists combating this pest should carry on experiments, but the worthlessness of kerosene as a factor of control was not demonstrated until a considerable literature upon the subject had been published. Kerosene is ineffective, inasmuch as it attracts for the most part only

males. Of 2,639 adults, representing four lots examined by the writers, only eight were females. Only 36 of 10,239 adults captured by Severin were females. Many thousands of adults captured in kerosene oil in connection with the present investigations have demonstrated the worthlessness of kerosene as a factor in reducing the infestation of fruit.

While the use of kerosene to trap the adults of the Mediterranean fruit fly is of no value in checking the ravages of this pest, the writers have made use of the number of males captured in traps to arrive at conclusions regarding the relative abundance of adults in any given area. The use of the kerosene trap for this purpose when supplemented by other observations has a value, provided conclusions are not attempted from too small a number of catches. The writers have data on file covering the number of flies caught in 292 traps for 16 consecutive months. As a rule traps hung in dense foliage of any sort captured more flies, while traps hung on porches and set upon stumps or in other exposed situations from 30 to 80 feet away from foliage captured only an occasional male. It would seem that in countries where host trees and shrubs are less abundant than in Hawaii the number of flies caught could be used as a basis for valuable deductions on such subjects as seasonal abundance and migrations of adults.

Description of trap.—The trap used by the writers is a simple affair consisting of an ordinary pie tin suspended by three tin strips from a tin cone through the top of which extends a wire by which the entire trap may be suspended from a branch. A trap can be made cheaply by any tinsmith. If properly painted, traps will last several seasons. The pan may be removed as often as desired. In Honolulu the oil was replenished every 2 or 3 days. In dry areas no protective covering for the pan containing the oil is needed. Oil to cover the bottom of the container to a depth of one-fourth of an inch is sufficient. The trap should be so long that no oil will spread to the bark of the tree.

SUBMERGENCE IN WATER.

Submergence of host fruits as a method of control has been recommended many times by writers and investigators of fruit flies. Harris recommended weighting sacks of infested fruit and sinking them at sea. Gurney found that larvæ in sea water in test tubes pupated at the surface against the glass and that a large percentage of larvæ in oranges submerged in cold water for 6, 8, 24, and 45 hours survived, pupated, and matured into normally healthy adults, and concluded that no casual treatment such as throwing infested fruit into a stream can be considered an effective method of destroying fruit-fly larvæ. Severin showed that many well-grown larvæ found floating on the top of a barrel of water, into which infested oranges had been thrown 24 hours previous, resumed activity within several hours after being placed on moist filter paper, in spite of the fact

that they were distended and apparently dead when removed from the water. A small percentage of other larvæ taken from the water after 3 days showed traces of life, but no adults developed from the fruit submerged for 4 days.

With the temperature ranging between 67° and 80° F. the writers were able to demonstrate that well-grown larvæ placed in tightly stoppered vials of fresh water died by the end of the third day. Thus 486 of 490 larvæ survived submergence 21 hours, 96 of 100 for 24 hours, and 78 of 100 for 48 hours; two lots of 100 larvæ each submerged 70 and 74 hours, respectively, were dead. It was found, however, that larvæ live longer when placed in water in open vials. Under such conditions certain individuals may remain suspended from the surface film of water much as do mosquito larvæ and pupæ. This is made possible by the circlet of small hairs about the posterior stigmal plates. While larvæ ordinarily become rigid and apparently dead within 2 or 3 hours after submergence in water, larvæ thus suspended were found to remain active for as long as 7 days in one instance. One larva removed to fresh fruit after suspension for 5 days pupated 7 days later and emerged as an adult after 9 days in the pupa stage.

TABLE XXXI.—*Effect of submergence of host fruits in water upon the larvæ of the Mediterranean fruit fly.*

Number hours immersed.	Host fruit.	Number of fruits examined.	Dead larvæ.			Living larvæ.		
			First instar.	Second instar.	Third instar.	First instar.	Second instar.	Third instar.
23	Apple	4	4	0	64	0	106	18
41		2	104	81	0	0	4	0
72		6	0	91	32	0	0	0
94		8	0	262	107	0	0	0
4	Winged kamani	21	0	0	0	0	63	279
22		22	0	0	5	0	113	448
49		23	0	0	88	0	0	51
72		33	0	0	179	0	0	12
96		253	0	0	1,376	0	0	1
98		21	0	0	142	0	0	0
120		34	0	0	147	0	0	0
4	Rose apple	4	36	80	0	0	0	0
24		5	0	9	0	0	8	17
70		50	0	0	217	...	...	...
72		1	0	12	0	0	0	0
98		3	0	37	0	0	0	0
18	Chinese orange	94	0	123	189	...	72	97
45		39	0	71	163	...	...	3
69		34	0	0	191	...	...	...
72		162	...	...	205	...	...	...
94		50	...	57	98	...	...	...
116		33	...	...	22	...	...	...
18	Guava	9	...	63	9	...	51	168
46		4	...	...	45	...	...	3
69		4	...	19	65	...	...	...
94		7	...	...	61	...	...	...
49	Strawberry guava	35	...	...	14	...	...	11
72		54	...	17	37	...	...	...
96		107	...	...	38	...	17	...
4	*M. elengi*	5	28	...	...	...	40	36
74	Orange	2	...	9	5	...	...	...
96		6	...	14	87	...	...	...
121		8	...	9	32	...	...	...
66	Peach	58	...	...	156	...	...	2
91		50	...	...	422	...	...	...

The examination of various host fruits submerged in ordinary tap water, when the temperature ranged between 67° and 80° F., gave the data recorded in Table XXXI. The data indicate that while larvæ are little affected after 1 or 2 days of submergence, a large percentage are dead after submergence for 3 days. Seventeen second-instar larvæ and 1 third-instar, however, were found living after submergence for 4 days. It is safe to conclude that submergence for 5 days will either kill all larvæ or incapacitate them for further development. It might be added that fruits held in water for as long as 3 to 5 days are, in Hawaii, rendered unfit as food for fruit-fly larvæ after removal from water.

TABLE XXXII.—*Effect of submergence in tap water upon pupæ of the Mediterranean fruit fly.*

Lot number.	Number of pupæ under observation.	Number of days immersed.	Date of pupation.	Date of immersion.	Date of removal.	Number of adult C. capitata emerging.	Number of adult Opius humilis emerging.	Date of emergence.
1	1,016	2	June 14–17	June 24	June 26	650	3	June 27–28
						191	15	June 29.
						4	18	June 30.
						....	16	July 4.
						....	1	July 5.
2	440	3	...do...	...do...	June 27	62	0	July 1.
						16	3	July 2.
						1	1	July 3.
3	312	4	...do...	...do...	June 28	4	0	July 1.
						3	0	July 2.
						0	1	July 4.
4	410	5	...do...	...do...	June 29	0	0	
5	258	6	...do...	...do...	June 30	1	0	July 7.
6	214	7	...do...	...do...	July 1	0	0	
7	950	2	June 17–22	...do...	June 26	32	0	June 29.
						207	5	June 30.
						190	7	July 1.
						156	18	July 3.
						39	8	July 4.
						6	0	July 5.
						18	2	July 6.
8	460	3	...do...	...do...	June 27	64	0	July 1.
						76	....	July 3.
						41	....	July 4.
						16	....	July 5.
						9	1	July 6.
						3	....	July 9.
9	210	4	...do...	...do...	June 28	1	....	July 1.
						25	....	July 3.
						23	3	July 4.
						9	2	July 5.
						17	....	July 6.
						19	1	July 7.
						1	1	July 8.
10	557	5	...do...	...do...	June 29	2	....	July 3.
						19	....	July 4.
						19	....	July 5.
						42	....	July 6.
						18	....	July 7.
						22	....	July 8.
						5	....	July 9.
11	372	6	...do...	...do...	June 30	13	....	July 7.
						6	....	July 8.
						3	....	July 10.
						3	....	July 12.
12	476	7	...do...	...do...	July 1	0	0	
Total	5,675							

Pupæ from 1 to 4 days old were submerged in vials of tap water when the temperature ranged from 72° to 85° F. A record of the

emergence from these pupæ is given in Table XXXII. The data covering lots 1 to 6 show that the more mature pupæ succumbed to immersion more quickly than the younger pupæ of lots 7 to 12. Thus many of the young pupæ emerged as adults after being submerged 4, 5, and 6 days, while submergence for these periods killed nearly all the older pupæ. Submergence for at least 7 days is necessary to assure the death of all pupæ.

BURIAL IN SOIL.

Many entomologists have made statements regarding the efficacy of burying infested fruits in the soil as a method of destroying fruit flies. These references have been summarized by Severin, hence need not be considered at length here, particularly as they deal with a method that is decidedly unsatisfactory and seldom effective. Gurney found that pupæ buried 6, 8, and 12 inches below the surface of the soil produced adults that were able to escape. Severin found that adults could make their way to the surface from pupæ buried 2, 3, and 4 feet beneath dry sand, and from pupæ buried 2 feet beneath wet sand, but that no adults escaped through 2, 3, or 4 feet of dry soil. Mally found that 10 inches of soil shoveled loosely over fruits did not prevent adults from escaping later, but that no adults could reach the surface through 10 inches of well-tamped soil. No adults escaped from 20 pupæ placed in the center of a cake of mud one-half inch square taken from the heavy, tenacious soil of the vegetable gardens at Waikiki. The mud became thoroughly dry without cracks before the end of the normal pupa stage. A cake of the same soil $1\frac{1}{2}$ inches square, however, on drying developed a crack through which 50 adults made their escape from 75 pupæ buried within the center of the square. While adults can not make their way through a foot of well-tamped soil, it is difficult to bury host fruits in such a manner that the soil covering will remain firm. The rapid decay and settling of fruit, if any amount be buried in the same excavation, cause cracks to develop through which adults can escape readily. While many fruit flies can be killed by proper burial, indifference and carelessness among workmen will always make possible the escape of many adults.

BURNING AND BOILING HOST FRUITS.

Burning or boiling host fruits is a sure method of destroying the immature stages of the Mediterranean fruit fly provided the work is feasible and can be done thoroughly. The usual practice of throwing fallen infested fruits into a compost pit and burning over them every few days such trash as may have accumulated is not a trustworthy method of destruction, inasmuch as the heat produced is very often insufficient to cook or burn the fruit thoroughly or to reach the pupæ in the soil beneath the fruit.

SUMMARY.

The Mediterranean fruit fly (*Ceratitis capitata*) was discovered at Honolulu in the Hawaiian Islands in 1910. Since that time it has spread to all the islands of the Hawaiian group, and because of the equable climate and abundance of host fruits, has effected a serious and permanent check to horticultural pursuits, and put an end to all export trade in fruits except that in bananas and pineapples.

Research seems to have fixed the native home of *C. capitata* in tropical Africa. Its spread has been slow but persistent throughout tropical and semitropical countries, until at the present time it is known to have become a pest in every continental area except that of North America. With the Mediterranean fruit fly now well established in Bermuda and the Hawaiian Islands, it would seem that it is only a matter of time before it will be inadvertently introduced and become established in California and the Southern States. The frequent interception and destruction of infested fruits from Hawaii at California ports, by officers of the Federal Horticultural Board, indicates the ease with which the introduction of the Mediterranean fruit fly might occur were Hawaiian fruit permitted unrestricted entry to the mainland of the United States.

No edible fruit in Hawaii, except the pineapple, escapes attack. The banana, when in good condition, is never infested, infestation having been noted only when the fruits were overripe or injured. The Mediterranean fruit fly has been reared in Honolulu from 72 species of host fruits, including the peach, plum, pear, guava, mango, orange, lemon, grapefruit, banana, etc. A large proportion of the host fruits are inedible. Throughout the littoral regions a continuous cycle of host fruits is available for infestation throughout the year; hence there are no starvation periods for the fly to survive.

With such a quantity and variety of host fruits, nuts, and vegetables in which to propagate, and enjoying an ideal climate, the mean temperatures of which vary between 68° and 79° F. for the regions in which the fly is a most serious pest, the Mediterranean fruit fly finds no check to its rapid increase. While a single generation may require as few as 17 days during the warmest weather, there are usually 15 to 16 generations a year at Honolulu, and 10 to 12 generations in areas where the winter mean drops to 68° F. There is considerable variation in the length of the immature stages, particularly during the coolest weather. Inasmuch as adults have been kept alive for 10 months and may deposit eggs in lots of a few to 32 daily quite regularly throughout life, the generations become hopelessly confused. While adults are not forced in Hawaii to pass through periods of several months when food is not available for oviposition, females deprived of host fruits for such periods will resume active and normal oviposition when the fruits become avail-

able. One female deposited 622 eggs between June 4 and September 2. The long adult life, and the ability of the female to deposit eggs regularly succeeding the period of from 4 to 8 days after emergence which is required to complete sexual maturity, make it possible for the annual progeny of a single pair of adults to reach enormous numbers.

Attempts at control by clean culture have been failures, owing largely to insurmountable obstacles placed in the way of man by a favorable climate and an unprecedented quantity of varied host fruits. Many fruits and nuts subject to attack grow on huge trees which blossom irregularly, and produce, in many instances, fruit susceptible to attack throughout the year. There is no procedure by which clean culture may be made effective under the present Hawaiian cultural methods. The islands are thoroughly overrun with the fruit fly, and this applies quite as much to the wild guava scrub in pastures, on lava flows, and in mountain valleys and ravines, as it does within the city limits. By far the larger number of host trees and shrubs are grown more for the protection they offer from the semitropical sun and for their ornamental value than for their inedible fruits. The destruction of host vegetation will not be practicable until it can be demonstrated that a distinct advantage would be gained thereby. To destroy all host trees of Honolulu at the present time would be to remove a large percentage of her prized vegetation without any compensating returns.

The ideal climatic and host conditions of Hawaii have rendered less effective and impracticable the usual artificial methods of control the value of which has been demonstrated in other countries possessing natural features less favorable to fruit-fly increase. At the present time the only hope of relief lies in the establishment of parasites. Six parasites have been introduced during the past three years and are now well established. While they have more than repaid the Territory of Hawaii for the cost of their introduction by bringing about an improved condition in the coffee-growing industry, it is doubtful whether they will effect a sufficient decrease in the proportion of infested host fruits to be considered efficient factors in control. This conclusion appears inevitable in spite of the remarkable success attendant on their introduction, unless a campaign is inaugurated for a reapportionment of host fruits; otherwise the hordes of adult flies maturing in thick-meated fruits, or in fruits protecting larvæ by other means from attack by parasites, will neutralize the effective work of parasites attacking larvæ in thin-skinned and thin-pulped fruits. There is great need of an effective egg parasite that will kill the fruit fly before the larva can do injury.

From a practical or commercial standpoint the results of the investigations reported herewith are of value (1) in furnishing data to

determine the probable range of this pest should it be introduced and gain a foothold in continental United States; (2) in verifying the practicability of poison sprays; (3) in indicating the utilization of cold-storage temperatures in making safe the movement of fruits from areas which might otherwise be cut off by quarantines from outside markets; and (4) in placing upon a sound basis the banana and pineapple export trade of the Hawaiian Islands.

At 50° F. little if any development takes place, and freezing temperatures can be withstood successfully only for short periods. Accumulated data indicate that the Mediterranean fruit fly will not become a serious pest in climates where the mean temperature is below 50° F. during periods covering three months of the year.

While Hawaiian conditions are unfavorable to the use of poison sprays, the work of the writers has convinced them that these sprays can be employed as successfully in combating this pest in commercial orchards of California and of Southern States, should they ever become infested, as in Africa and Australia.

While at present cold storage is not utilized to modify existing quarantine, it is a recognized fact that, commercially used, it has been of value in safeguarding fruits from additional infestation while en route over long distances. The data set forth herewith indicate for the first time the duration of time required for various temperature ranges to kill the stages of the fruit fly within stored fruits, and from these records it is reasonable to conclude that the certification of properly refrigerated fruit is practicable. When an association of fruit growers or the people discover that refrigeration is financially worth while, there is reason to believe that it will result in the operation of central refrigeration plants under the supervision of officers whose guarantee will insure that all fruits sent out from the plant are absolutely free from danger as carriers of the Mediterranean fruit fly.

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